Advancement of IoT-Based Smart Systems for Real-Time Sports Performance Analysis: Potential and Challenges

Abdul Nasir, Devin Babu, M. H. Muhammad Sidik, Norain Binti Abdullah, and Waheb A. Jabbar

Abstract Internet of Things (IoT) technology in the field of sports has brought about a significant transformation in the analysis of athletic performance, as it facilitates the seamless collection and processing of data in real time. Nevertheless, enduring obstacles encompass issues pertaining to data security, privacy, and the imperative for resilient real-time data processing capabilities. Mainly, data transfer rate is very important when it is related to real-time application. However the emergence of 5G, edge computing, machine learning, and artificial intelligence offers substantial prospects for augmenting the functionalities of these systems. This enhancement would result in more precise and prompt understandings of athletes' performances, improvised training plan for specific objectives, and high potentially able to decrease risk of common injury. However, there are limitations even though these kinds of technologies have been implemented. On the other hand, cyber physical attacks threat is another aspect that must be taken into consideration in developing IoT devices. This article would also help the readers and researchers to understand the

A. Nasir · D. Babu
Faculty of Electrical and Electronic Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia
e-mail: abdnasir@umpsa.edu.my

M. H. Muhammad Sidik (✉)
Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia
e-mail: hanafisidik@umpsa.edu.my

N. B. Abdullah
Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia

Bio-Coke Research Institute, Kindai University, Osaka, Japan

W. A. Jabbar
School of Engineering and Built Environment, Birmingham City University, Birmingham, West Midlands, England, UK

importance of data processing, smart systems, security and privacy and future trends in IoT application for sports performance analysis.

Keywords Internet of Things · Sports performance analysis · Real-time data processing · Smart systems · Data security

1 Importance of IoT in Sports Performance Analysis

The Internet of Things (IoT) has brought a significant transformation in various industries such as manufacturing, agriculture, medical and healthcare, and even in sports (Pires and Santos 2018; Rejeb et al. 2022; Jain et al. 2021; Abdulmalek et al. 2022). This modern industrial evolution is supported by utilization of IoT due to its ability to facilitate real-time data collection and analysis (Yu and Wang 2020; Jamil et al. 2021; Babu et al. 2021). Internet of Things (IoT) devices, such as wearable sensors and smart equipment, have the capability to gather a wide range of data points, encompassing metrics such as an athlete's heart rate, speed, movement patterns, and other relevant information. The aforementioned data can subsequently be subjected to analysis in order to derive valuable insights pertaining to an athlete's performance, pinpoint areas that require enhancement, and potentially forecast and preempt potential injuries (Silvers-Granelli et al. 2021). The incorporation of Internet of Things (IoT) technology in sports performance analysis has resulted in the emergence of intelligent systems capable of promptly processing and evaluating data (Rosli et al. 2021; Nižetić et al. 2020). These systems have the capability to offer real-time feedback to athletes and coaches, enabling them to make necessary adjustments during training sessions or competitions. An intelligent system has the capability to analyze the data obtained from a runner's wearable device, subsequently offering immediate feedback regarding their running technique (Clermont et al. 2019). This feedback serves the purpose of enhancing efficiency and mitigating the likelihood of sustaining injuries.

Moreover, the integration of Internet of Things (IoT) technology in smart systems has the potential to make significant contributions to the expansive domain of sports science (Baharuddin et al. 2022; Schlegel and Hill 2020). This is achieved through the provision of extensive datasets that can be utilized for research purposes. The utilization of these datasets facilitates the examination of patterns, the identification of optimal strategies, and the formulation of novel approaches to training (Khan et al. 2022). Nevertheless, the integration of Internet of Things (IoT) technology in the realm of sports performance analysis presents certain obstacles. Significant considerations encompass data security, privacy, and the imperative for robust, real-time data processing capabilities (Khoshkhah et al. 2022; Rosli et al. 2019).

The objective of this review is to offer a comprehensive examination of the present condition of Internet of Things (IoT)-based intelligent systems for the analysis of real-time sports performance. The review will additionally put forth potential remedies for these deficiencies, offering a strategic plan for future investigation and advancement.

2 IoT and Real-Time Data Processing

2.1 The Role of IoT in Real-Time Data Collection

The Internet of Things (IoT) has brought about a paradigm shift in the field of data collection by facilitating the seamless acquisition of real-time and continuous data from diverse sources. In sports performance analysis, Internet of Things (IoT)-based devices, such as wearable sensors, smart equipment, and video surveillance systems, have the capability to gather a diverse range of data points. These data points encompass an athlete's physiological parameters, movement patterns, and environmental conditions (Zhou et al. 2021). Zhou et al. examined the application of Internet of Things (IoT) technology in surveillance systems, emphasizing the significance of real-time data acquisition for efficient monitoring and decision-making processes (Zhou et al. 2021). In sport science, the collection of real-time data can offer prompt insights into an athlete's performance, enabling on-the-spot adjustments to be made during training sessions or competitive events. Lukas et al. introduced SPORTSENSE, a video-based event retrieval system. This system can visualize the analysis results in real time, store the analysis results persistently for offline activities, and leverage the stored analysis results for intuitive sketch-based video retrieval as in Fig. 1 (Probst et al. 2018).

On the other hand, Jamali and Giman emphasized the utilization of the Internet of Things (IoT) for the purpose of collecting real-time data for flood monitoring (Jamali and Giman 2021). While the principles of real-time data collection and monitoring may not have a direct correlation to sports performance analysis, they possess similarities that allow for their application within the sports domain, especially to monitor the environmental changes that might affect the athlete performance and health (Jamaludin et al. 2018a; Jamali and Giman 2021; Abdullah et al. 2022; Donnelly et al. 2016; Nowak et al. 2022). Sven et al. conclude that climate change is associated with the increases in health-related risks for athletes such as UV exposure, heat stress, UV exposure, exposure to air pollutants, spread of vectors, and natural reservoirs as well as other risks such as extreme weather events (Schneider and Mücke 2021). Thus, monitoring systems that are focusing on feeding affirmative information about surrounding environmental changes during sports activity are crucially needed (Hasya et al. 2022; Torres-Ronda et al. 2022; Md Kamil et al. 2022; Alexandersen et al. 2023). For example, Mainura et al. proposed an improved fuzzy

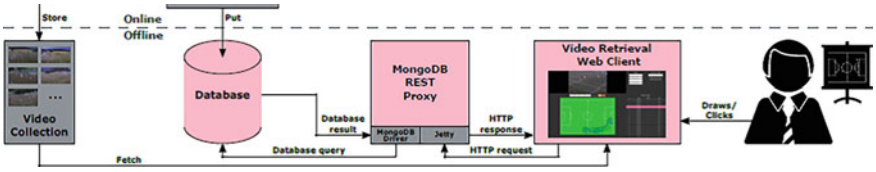

Fig. 1 Architecture of SPORTSENSE system (Probst et al. 2018)

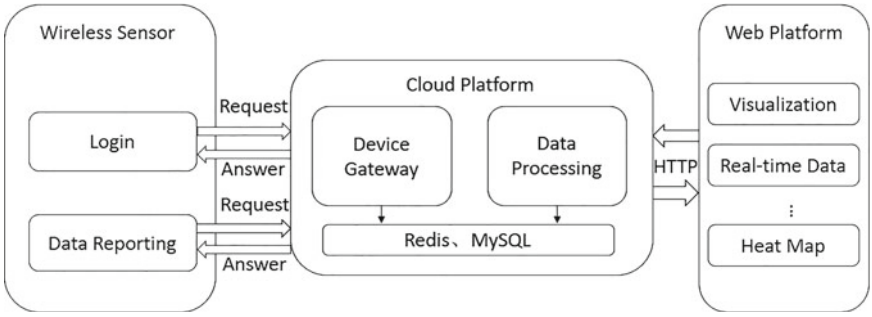

Fig. 2 Architecture of outdoor air quality monitoring system for sports athlete (Li and Xu 2021)

logic-based controller for humidity monitoring control in sports halls. Then, Juan Li et al. as in Fig. 2 developed a real-time online monitoring system for outdoor air quality for sports athletes (Li and Xu 2021).

2.2 Real-Time Data Processing and Decision-Making

After the collection of data in real time, it is necessary to undertake processing and analysis in order to derive significant insights. Real-time data processing is a crucial aspect in this context. Real-time data processing refers to the practice of analyzing data immediately after its collection, enabling prompt decision-making (Khan et al. 2022; Abidin et al. 2022; Sudharsan et al. 2021). In the study on sustainable smart cities, utilization of real-time routing and underscoring the significance of real-time data processing in facilitating efficient decision-making (Rehman et al. 2021; Rosli et al. 2021) found that a mobility support 5G architecture with real-time routing able to decrease the loss of data against network disconnectivity and increase the reliability. Figure 3 shows the success ratio when data rate is increased from 30 to 150 bits per second. Even though data rate is decreased, but it is still in acceptable range (Sachs et al. 2018).

In the field of sports performance analysis, the utilization of real-time data processing has the potential to offer instantaneous feedback regarding an athlete's performance (Silva et al. 2020; Yuan et al. 2020). This enables coaches and athletes to make well-informed decisions in the midst of training sessions or competitive events. Qingfeng proposed a computer big data-based technology real-time signal transmission system for sports competitions (Shi 2023). The proposed system is able to remove noise from signal transmission and also capable of detecting weak signals submerged in the background of strong color noise, which is superior to the traditional time domain detection method.

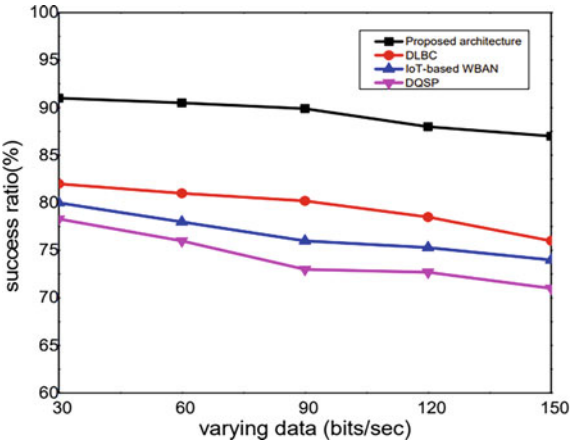

Fig. 3 Analysis of the success ratio under a varying data rate of 30 to 150 bits/s (Sachs et al. 2018)

2.3 Challenges in Real-Time Data Processing

Although real-time data processing in IoT-based systems offers numerous benefits, it is not devoid of challenges. These factors encompass the necessity for strong and dependable data processing capabilities, the management of substantial quantities of data, and the assurance of data security and privacy (Gurcan and Berigel 2018). The necessity for strong and dependable data processing capabilities is of utmost importance in order to guarantee accurate and timely processing of the collected data. The need for robust computational capabilities poses a significant challenge for IoT devices, given their inherent limitations in terms of processing power.

One additional challenge pertains to the management of substantial quantities of data. IoT devices have the capacity to accumulate substantial volumes of data, potentially surpassing the data processing capabilities of the system. Efficient data management strategies are necessary in order to ensure the processing of only pertinent data, thereby mitigating the system's workload. The preservation of data security and privacy poses a considerable obstacle. Due to the ability to gather and analyze data in real-time, IoT devices possess a susceptibility to being targeted by cyber-attacks. The implementation of robust security measures is necessary in order to safeguard data and guarantee the preservation of privacy (Khoshkhah et al. 2022; Ting et al. 2022).

3 Smart Systems and IoT

3.1 The Concept of Smart Systems in IoT

Smart systems in the context of the Internet of Things (IoT) pertain to systems that possess the capability to independently process and analyze data, make informed decisions based on the analyzed data, and execute actions without requiring human intervention. These systems utilize cutting-edge technologies such as machine learning, artificial intelligence, and cloud computing to offer intelligent and automated solutions (Rehman et al. 2021; Elkhoukhi et al. 2022). Sudharsan et al. investigated on real-time offensive words spotting network for consumer IoT devices (Sudharsan et al. 2021) and found that is capable of efficiently detecting multiple keywords in real-time. This system showcases the potential of intelligent systems to effectively process and analyze data in real time, enabling informed decision-making based on the analyzed information.

In a similar vein, Elkhoukhi explored the application of intelligent systems in the context of real-time occupancy detection within smart buildings (Elkhoukhi et al. 2022). The system showcases the potential of intelligent systems to effectively handle and analyze substantial amounts of data in real time, enabling them to derive insights and make informed decisions based on the analyzed data.

3.2 Application of Smart Systems in Sports Performance Analysis

The utilization of intelligent systems has demonstrated notable applications in the analysis of sports performance. The ability to extract and evaluate data from diverse sources, including wearable sensors, smart equipment, and video surveillance systems, enables the generation of valuable insights regarding an athlete's performance. This data analysis can identify areas that require improvement and even forecast and mitigate potential injuries (Kofahi et al. 2022; Ali et al. 2022; Liao et al. 2020). Kofahi et al. developed IoT-enabled intelligent system for Mixed Martial Arts (MMA) athletes that has the capacity to continuously monitor and measure the athlete's body temperature, strike force, and the number of strikes that the athlete has received from the opponent, providing promising real-time data analysis and decision-making capabilities (Kofahi et al. 2022). Figure 4 show the location of sensors on protection equipment and this study showcases the potential of smart systems to effectively process and analyze health-related information in real time, thereby facilitating informed decision-making.

Fig. 4 Implementation of integrated sensors on the proposed system (Shi 2023)

3.3 Limitations and Challenges of Current Smart Systems

Notwithstanding the inherent benefits, contemporary intelligent systems encounter various constraints and obstacles. The aforementioned factors encompass the necessity for resilient and dependable data processing capabilities, management of substantial quantities of data, assurance of data security and privacy and requirement for compatibility between various IoT devices and systems (Liao et al. 2020; Jamaludin et al. 2018b). The necessity for robust and dependable data processing capabilities is of utmost importance in order to guarantee accurate and timely processing of the collected data (Tramarin et al. 2019). The need for robust computational capabilities poses a significant challenge for IoT devices, given their inherent limitations in terms of processing power.

Dealing with substantial quantities of data presents an additional obstacle. IoT devices have the capacity to accumulate extensive volumes of data, potentially exceeding the data processing capabilities of the system. Efficient data management strategies are necessary to ensure the processing of only pertinent data, thereby mitigating the system's workload. The maintenance of data security and privacy presents a noteworthy challenge. Given their ability to gather and analyze data in real-time, IoT devices possess a susceptibility to cyber-attacks. The implementation of robust security measures is necessary in order to safeguard data and guarantee privacy (Tawalbeh et al. 2020; Ramli et al. 1060; Laghari et al. 2021). One additional challenge in the realm of IoT pertains to achieving interoperability across diverse devices and systems. The seamless communication and collaboration of IoT devices and systems are of utmost importance in facilitating the efficient operation of smart systems, given the growing proliferation of such devices and systems.

4 Security and Privacy in IoT-Based Systems

4.1 The Importance of Security in IoT Systems

The preservation of security holds significant importance in IoT systems, primarily due to the handling of sensitive data within these systems. In the field of sports performance analysis, IoT devices are utilized to gather a diverse range of data points (Laghari et al. 2021; Jamaludin et al. 2017; Manzoor et al. 2023). These data points encompass an athlete's physiological parameters, movement patterns, and the prevailing environmental conditions. If this data was to be accessed by unauthorized individuals, it has the potential to result in significant breaches of privacy or be exploited for nefarious intentions. In their research on IoT-based smart climate agriculture systems, Ting et al. emphasize the importance of safeguarding the security of IoT systems by encompassing not only the protection of the data they manage, but also the preservation of the system's integrity (Ting et al. 2022). A security breach has the potential to impede the operational integrity of the system, resulting in the generation of erroneous data and analysis, and potentially jeopardizing the well-being of the athletes.

4.2 Current Techniques for Ensuring Security and Privacy

Various methodologies are presently employed to safeguard the security and privacy of IoT systems. The aforementioned elements encompass encryption, authentication, and the utilization of secure communication protocols. In a study on the generation of daily modal split estimation and OD matrices using IoT data in application of secure communication protocols shows that the importance of secure communication protocols in guaranteeing the integrity of data exchanged between IoT devices and the system is underscored (Khoshkhah et al. 2022). Meanwhile, Xinyu et al. propose a cancelable biometric modality by utilizing a high-density surface electromyogram (HD-sEMG) encoded by hand gesture password, for user authentication. The proposed system will overcome a noncancelability of traditional biometrics (e.g., fingerprint) for user authentication that might increase the privacy disclosure risks once the biometric template is exposed. Based on the analysis result, the proposed system with 95% variance preserved, the security of the proposed HD-sEMG biometrics is equivalent to a 140-bit key with a total of 2^{140} expected attempts of brutal attack required to intrude the system. The security strength of HD-sEMG biometrics against brutal attack is presented in Table 1.

Table 1 Security strength against cyber attack

Preserved variance with PCA-based dependence removal	Entrophy E
100%	1318 bits
99%	313 bits
98%	238 bits
97%	198 bits
96%	164 bits
95%	140 bits

4.3 Challenges and Limitations in Ensuring Security and Privacy

Despite the existing methodologies, the task of safeguarding the security and privacy of IoT systems is accompanied by a multitude of obstacles. Several factors must be considered in the context of ensuring the security of devices, such as the imperative of employing strong encryption methods, the potential vulnerability to physical assaults, and the necessity of safeguarding data storage (Manzoor et al. 2023). The implementation of strong encryption methods is imperative in order to safeguard data integrity and confidentiality throughout the processes of transmission and storage. Nevertheless, the computational resources necessary for ensuring strong encryption pose a significant obstacle for IoT devices, which generally possess constrained processing capabilities.

One additional risk involves the potential for cyber and physical attacks on the devices (Shah and Sengupta 2020). IoT devices are frequently deployed in real-world environments, making them susceptible to physical attacks. This has the potential to result in the compromise of the device and unauthorized access to the collected data (Shah and Sengupta 2020; Lee et al. 2021; Bennett et al. 2018; Baharuddin et al. 2023; Li et al. 2019). The challenge of secure data storage is also evident. To mitigate the risk of unauthorized access, it is imperative to ensure secure storage of the substantial amounts of data amassed by IoT devices. The utilization of robust data storage solutions is imperative in addressing the challenge posed by the constrained storage capacities of IoT devices. Cyber and physical attacks can be detected based on energy auditing as in Fig. 5 (Bennett et al. 2018).

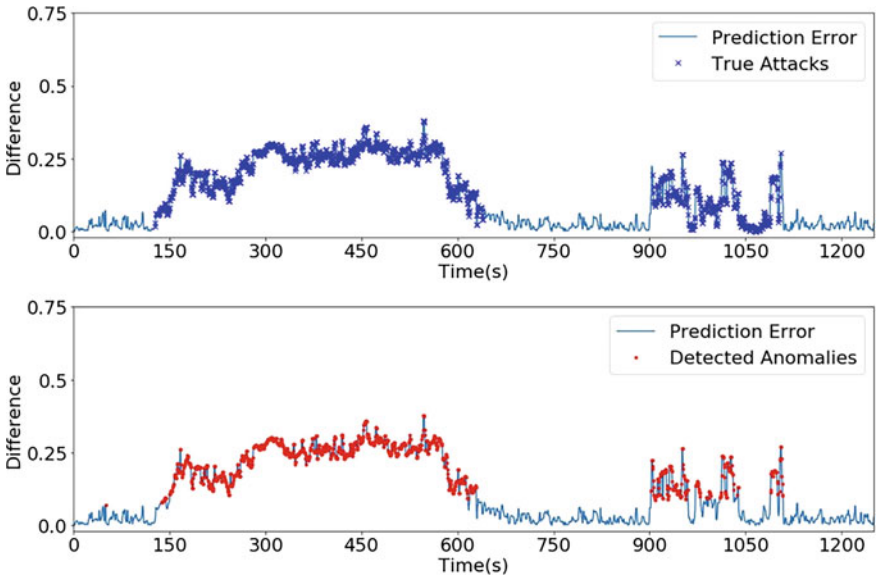

Fig. 5 Power prediction error with true attacks and detected anomalies. Cyber-attacks (between 900 and 1100 s) and physical attacks (between 150 and 600 s) (Li et al. 2019)

5 Future Trends and Opportunities

5.1 The Role of 5G and Edge Computing in IoT (Reference Jain et al. 2021)

The emergence of 5G and edge computing is poised to bring about a transformative impact on the IoT, particularly in sports performance analysis. The implementation of 5G technology has the potential to greatly augment the real-time data collection and processing capabilities of IoT devices, owing to its ability to facilitate high-speed data transfer (Li et al. 2019; Sufian et al. 2021; Zhao et al. 2019). This phenomenon has the potential to result in enhanced precision and promptness in the comprehension of an athlete's performance (Rehman et al. 2021). In contrast, edge computing refers to the practice of performing data processing tasks in close proximity to the source of data generation within a network. The implementation of this approach has the potential to decrease the latency that is typically encountered when transmitting data to a centralized location for processing. As a result, the real-time capabilities of IoT devices can be further improved (Rehman et al. 2021).

5.2 The Potential of Machine Learning and AI in IoT

The utilization of machine learning and artificial intelligence (AI) exhibits considerable promise within the realm of Internet of Things (IoT), specifically in the domain of sports performance analysis for predicting results, athletes profiling and performances, injuries diagnosis and even can be extended to predict advertising behaviors (Du et al. 2021; Worsey et al. 2021; Goud et al. 2019; Binti Kamarudin et al. 2021; Bunker and Thabtah 2019; Chhabra et al. 2023; Ghazali et al. 2022; Jamaludin and Yassin 2013 Naglah et al. 2018; Tedesco et al. 2022; Barnes and Wang 2023). The aforementioned technologies possess the capability to analyze the extensive quantities of data gathered by Internet of Things (IoT) devices in order to detect patterns, generate predictions, and offer insights that may not be readily discernible through conventional methods of analysis (Qian et al. 2022). In optimization of neural networks for time-series analysis in IoT systems in potential of machine learning and artificial intelligence, found that accuracy is improved compared without using any classifiers (Qian et al. 2022).

5.3 Opportunities for Future Research and Development

The progressions in technological domains such as 5G, edge computing, machine learning, and Artificial Intelligence (AI) offer substantial prospects for prospective investigations and advancements in IoT-based intelligent systems designed for the analysis of sports performance (Glebova et al. 2023). These encompass the advancement of more resilient and dependable data processing capabilities, the investigation of novel data collection methodologies, and the enhancement of more secure and privacy-centric systems. Moreover, there exists the potential to investigate the incorporation of additional nascent technologies, such as blockchain and quantum computing, within the realm of the IoT (Li and Zhu 2023; Khaund 2020; Yadav et al. 2023). The implementation of these technologies has the potential to significantly augment the security, privacy, and data processing functionalities of IoT systems. In addition, progress and achievement findings in sports science are high potentially can be implemented for public usage such as for wearable devices and healthcare monitoring.

Acknowledgements The author wishes to express profound gratitude to the Universiti Malaysia Pahang Al-Sultan Abdullah for their invaluable support and financial assistance under internal research grant scheme, RDU230328.

References

Abdullah NA, Abdullah FF, Sufian AH, Abidin AN, Jamaludin AS, Razali MN (2022) Effect of degradation by temperature onto nitrile rubber elastomer mechanical properties. Mater Today: Proc 48:1941–1946

Abdulmalek S, Nasir A, Jabbar WA, Almuhaya MA, Bairagi AK, Khan M-M, Kee S-H (2022) IOT-based healthcare-monitoring system towards improving quality of life: a review. Healthcare 10:1993

Abidin AN, Azmi AH, Kassim KA, Jamaludin AS, Razali MN (2022) A review on automotive tires significant characteristic identification for general consumers. In: Proceedings of the 2nd energy security and chemical engineering congress, pp 375–385

Alexandersen A, Pettersen SD, Johansen D (2023) Quantifying athlete wellness: investigating the predictive potential of subjective wellness reports through a player monitoring system

Ali MA, Sivarao, Abdullah Z, Izamshah R, Kassim MS, Jamaludin AS (2022) Multi-response optimization of machining simulation approach using grey relational analysis. Lecture Notes in Mechanical Engineering, pp 154–157

Babu D, Nasir A, Jamaludin AS, Rosle MH (2021) Holding, grasping and sensing of prosthetic robot arm like a real human hand, a journey beyond limits: an extensive review. In: Human-centered technology for a better tomorrow, pp 485–504

Baharuddin NJ, Abdul Manaf AR, Jamaludin AS (2022) Study on die shoulder patterning method (DSPM) to minimise springback of U-bending. Int J Autom Mech Eng 19:9509–9518

Baharuddin NJ, Manaf AR, Jamaludin AS (2023) Study of springback behavior on U-bending part using die shoulder patterning method (DSPM). Adv Mater Sci Manuf Eng

Barnes SJ, Wang W (2023) Understanding consumer advertising via audio analytics of sports videos. In: 5th international conference on artificial intelligence and information communication (ICAIIC 2023), pp 33–36

Bennett CL, Brady E, Branham SM (2018) Interdependence as a frame for assistive technology research and design. In: Proceedings of the 20th international ACM SIGACCESS conference on computers and accessibility

Binti Kamarudin SN, Lee H, Ishak I, Manaf AR, Jamaludin AS, Shaharudin MA, Zawawi MZ (2021) Rapid direct continuous method for hot embossing of glass microlens array combined with CO_2 laser irradiation and external preheating/cooling. Lecture Notes in Mechanical Engineering, pp 669–675

Bunker RP, Thabtah F (2019) A machine learning framework for sport result prediction. Appl Comput Inform 15(1):27–33

Chhabra G, Kumar S, Gupta S, Nagpal P (2023) Machine learning for individual performance analysis and sports analytics. In: Artificial intelligence to analyze psychophysiological human lifestyle, pp 113–127

Clermont CA, Duffett-Leger L, Hettinga BA, Ferber R (2019) Runners' perspectives on 'smart' wearable technology and its use for preventing injury. Int J Human-Comput Interact 36:31–40

Donnelly AA, MacIntyre TE, O'Sullivan N, Warrington G, Harrison AJ, Igou ER, Jones M, Gidlow C, Brick N, Lahart I, Cloak R, Lane AM (2016) Environmental influences on Elite sport athletes well being: from gold, silver, and bronze to blue green and gold. Front Psychol 7

Du X, Fuqian X, Hu J, Wang Z, Yang D (2021) Uprising E-sports industry: machine learning/AI improve in-game performance using deep reinforcement learning. In: Proceedings of the 2021 international conference on machine learning and intelligent systems engineering (MLISE 2021), pp 547–552

Elkhoukhi H, Bakhouya M, El Ouadghiri D, Hanifi M (2022) Using stream data processing for real-time occupancy detection in smart buildings. Sensors 22:2371

Ghazali NF, Shahar N, As'ari MA (2022) Badminton strokes recognition using inertial sensor and machine learning approach. In: 2022 2nd international conference on intelligent cybernetics and technology applications (ICICyTA 2022), pp 1–5

Glebova E, Gerke A, Book R (2023) The transformational role of technology in sports events. Sports Manag Uncertain Environ 169–187
Goud PSHV, Roopa YM, Padmaja B (2019) Player performance analysis in sports: with fusion of machine learning and wearable technology. In: International conference on computing methodologies and communication (ICCMC), pp 600–603
Gurcan F, Berigel M (2018) Real-time processing of big data streams: lifecycle, tools, tasks, and challenges. In: ISMSIT 2018—2nd international symposium on multidisciplinary studies and innovative technologies, proceedings
Hasya N, Razali MNM, Jamaludin AS, Saffe SNBM, Hadi MA (2022) Micromilling performance analysis—cold air assisted aluminium machining behaviour observation. In: Innovative manufacturing, mechatronics & materials forum 2022 (iM3F 2022), online conference, Pekan, Malaysia, pp 124–130
Jain V, Mishra AK, Ojha MK (2021) The impact of internet of things in manufacturing industry. Lecture Notes in Mechanical Engineering, pp 517–527
Jamali A, Giman JP (2021) Performance analysis of IOT based flood monitoring framework in sub-urban. In: 2021 IEEE 7th international conference on smart instrumentation, measurement and applications (ICSIMA 2021), pp 99–104
Jamaludin AS, Yassin A (2013) Analysis of laser sintered materials using finite element method. Sains Malaysiana 42(12):1727–1733
Jamaludin AS, Hosokawa A, Furumoto T, Koyano T, Hashimoto Y (2017) Evaluation of the minimum quantity lubrication in orthogonal cutting with the application of finite element method. Int J Mech Mechatron Eng IJMME-IJENS 17(01):104–109
Jamaludin AS, Hosokawa A, Furumoto T, Koyano T, Hashimoto Y (2018) Study on the effectiveness of extreme cold mist MQL system on turning process of stainless steel Aisi 316. IOP Conf Series: Mater Sci Eng 319:012054
Jamaludin AS, Akira H, Furumoto T, Koyano T, Hashimoto Y (2018) High precision estimation on physical behavior for cutting with various tool rake angle by finite element method. Lecture Notes in Mechanical Engineering, pp 715–723
Jamil H, Umer T, Ceken C, Al-Turjman F (2021) Decision based model for real-time IOT analysis using big data and machine learning. Wirel Pers Commun 121:2947–2959
Khan MG, Huda NU, Zaman UK (2022) Smart warehouse management system: architecture, real-time implementation and prototype design. Machines 10:150
Khaund S (2020) Blockchain: from Fintech to the future of sport. 21st century sports 191–203
Khoshkhah K, Pourmoradnasseri M, Hadachi A, Tera H, Mass J, Keshi E, Wu S (2022) Real-time system for daily modal split estimation and OD matrices generation using IOT data: a case study of tartu city. Sensors 22:3030
Kofahi NA, Al-Khatib RM, Alomari A, Mansi TA (2022) A smart real-time IOT-based system for monitoring health of athletes. Int J Comput Digit Syst 12:141–148
Laghari AA, Wu K, Laghari RA, Ali M, Khan AA (2021) Retracted article: a review and state of art of internet of things (IOT). Archiv Comput Methods Eng 29:1395–1413
Lee H, Binti Kamarudin SN, Ishak I, Manaf AR, Jamaludin AS, Shaharudin MA, Zawawi MZ (2021) Feasibility Study of wafer scale laser assisted thermal imprinting of glass nanostructures. Lecture Notes in Mechanical Engineering, pp 917–923
Li N, Zhu X (2023) Design and application of blockchain and IoT-enabled sports injury rehabilitation monitoring system using neural network. Soft Comput 27:11815–11832
Li F, Shi Y, Shinde A, Ye J, Song W (2019) Enhanced cyber-physical security in internet of things through energy auditing. IEEE Internet Things J 6:5224–5231
Li J, Xu J (2021) Outdoor air quality real-time monitoring system for sports athletes. In: IEEE advanced information technology, electronic and automation control conference
Liao B, Ali Y, Nazir S, He L, Khan HU (2020) Security analysis of IOT devices by using mobile computing: a systematic literature review. IEEE Access 8:120331–120350
Manzoor SI, Jain S, Singh Y, Singh H (2023) Federated learning based privacy ensured sensor communication in IOT networks: a taxonomy, threats and attacks. IEEE Access 11:42248–42275

Md Kamil NH, Jamaludin AS, Mhd Razali MN, Abd. Ghaffar AN (2022) Temperature and heat flow analysis in a drying chamber through finite element method. Lecture Notes in Mechanical Engineering, pp 309–316

Naglah A, Khalifa F, Mahmoud A, Ghazal M, Jones P, Murray T, Elmaghraby AS, El-baz A (2018) Athlete-customized injury prediction using training load statistical records and machine learning. In: 2018 IEEE international symposium on signal processing and information technology (ISSPIT)

Nižetić S, Šolić P, López-de-Ipiña González-de-Artaza D, Patrono L (2020) Internet of things (IOT): Opportunities, issues and challenges towards a smart and sustainable future. J Clean Prod 274:122877

Nowak AS, Kennelley GE, Krabak BJ, Roberts WO, Tenforde KM, Tenforde AS (2022) Endurance athletes and climate change. J Climate Change Health 6:100118

Pires M, Santos V (2018) Assessing the impact of internet of everything technologies in football. Adv Intell Syst Comput 745:375–388

Probst L, Rauschenbach F, Schuldt H, Seidenschwarz P, Rumo M (2018) Integrated real-time data stream analysis and sketch-based video retrieval in team sports. In: 2018 IEEE international conference on big data (Big Data)

Qian C, Einhaus L, Schiele G (2022) ElasticAI-creator: optimizing neural networks for time-series-analysis for on-device machine learning in IoT systems. In: Proceedings of the 20th ACM conference on embedded networked sensor systems (SenSys 2022), pp 941–946

Ramli MR, Razak NA, Ismail I, Jamaludin AS, Manaf AR (2022) Effect of dimple size onto wear rate of mild steel AISI 1060 Surface. Lecture Notes in Mechanical Engineering, pp 99–102

Rehman A, Haseeb K, Saba T, Lloret J, Ahmed Z (2021) Mobility support 5G architecture with real-time routing for sustainable smart cities. Sustainability 13:9092

Rejeb A, Rejeb K, Abdollahi A, Al-Turjman F, Treiblmaier H (2022) The interplay between the internet of things and agriculture: a bibliometric analysis and research agenda. Internet of Things 19:100580

Rosli AM, Jamaludin AS, Razali MNM (2021) Recent study on hard to machine material—micromilling process. Evergreen 8:445–453

Rosli AM, Jamaludin AS, Razali MN, Sani AS, Hamzah SB, Osman MS (2019) Modelling of fuzzy inference system for micro milling—a preliminary study through FEM. Lecture Notes in Mechanical Engineering, pp 445–456

Rosli AM, Jamil N, Jamaludin AS, Razali MN, Yusoff AR (2021) Tool wear observation during unconventional low speed machining using low cost micromilling. Lecture Notes in Mechanical Engineering, pp 589–597

Sachs J, Wikstrom G, Dudda T, Baldemair R, Kittichokechai K (2018) 5G radio network design for ultra-reliable low-latency communication. IEEE Netw 32:24–31

Schlegel MU, Hill C (2020) The reach of sports technologies. Lecture Notes in Mechanical Engineering, pp 91–110

Schneider S, Mücke HG (2021) Sport and climate change—how will climate change affect sport? German J Exerc Sport Res

Shah Y, Sengupta S (2020) A survey on classification of cyber-attacks on IoT and IIoT devices. In: Ubiquitous computing, electronics and mobile communication conference

Shi Q (2023) Research on real-time signal transmission system of competitive sports competition under computer big data technology. In: 2023 IEEE international conference on control, electronics and computer technology (ICCECT)

Silva AF, Conte D, Clemente FM (2020) Decision-making in youth team-sports players: a systematic review. Int J Environ Res Public Health 17:3803

Silvers-Granelli HJ, Cohen M, Espregueira-Mendes J, Mandelbaum B (2021) Hamstring muscle injury in the athlete: state of the art. J ISAKOS 6:170–181

Sudharsan B, Malik S, Corcoran P, Patel P, Breslin JG, Ali MI (2021) OWSNet: towards real-time offensive words spotting network for consumer IOT devices. In: 2021 IEEE 7th world forum on Internet of Things (WF-IoT)

Sufian AH, Xun TZ, Abidin AN, Jamaludin AS, Razali MN (2021) Study on tire tread design effect onto tire-road contact behavior through FEM. Lecture Notes in Mechanical Engineering, pp 893–902

Tawalbeh L, Muheidat F, Tawalbeh M, Quwaider M (2020) IOT privacy and security: challenges and solutions. Appl Sci 10:4102

Tedesco S, Scheurer S, Brown KN, Hennessy L, O'Flynn B (2022) A survey on the use of artificial intelligence for injury prediction in sports. In: 2022 IEEE international workshop on sports technology research (STAR 2022)—Proceedings, pp 127–131

Ting L, Khan M, Sharma A, Ansari MD (2022) A secure framework for IOT-based smart climate agriculture system: toward Blockchain and edge computing. J Intell Syst 31:221–236

Torres-Ronda L, Beanland E, Whitehead S, Sweeting A, Clubb J (2022) Tracking systems in team sports: a narrative review of applications of the data and sport specific analysis. Sports Med—Open 8

Tramarin F, Mok AK, Han S (2019) Real-time and reliable industrial control over wireless lans: algorithms, protocols, and future directions. Proc IEEE 107:1027–1052

Worsey MTO, Espinosa HG, Shepherd JB, Thiel DV (2021) One size doesn't fit all: supervised machine learning classification in athlete-monitoring. IEEE Sens Lett 5(3)

Yadav J, Misra M, Rana NP, Singh K, Goundar S (2023) Blockchain's potential to rescue sports: a social media perspective. In: Distributed computing to blockchain architecture, technology and applications, pp 405–414

Yu T, Wang X (2020) Real-time data analytics in Internet of Things systems. In: Handbook of real-time computing, 1–28

Yuan C, Yang Y, Liu Y (2020) Sports decision-making model based on data mining and neural network. Neural Comput Appl 33:3911–3924

Zhao L, Matsuo IBM, Zhou Y, Lee WJ (2019) Design of an industrial IoT-based monitoring system for power substations. IEEE Trans Ind Appl 55(6):5666–5674

Zhou X, Xu X, Liang W, Zeng Z, Yan Z (2021) Deep-learning-enhanced multitarget detection for end–edge–cloud surveillance in smart IOT. IEEE Internet Things J 8:12588–12596