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Research Article

Intelligent System for Training and Assessment of Basketball Referee in Sports Event Using Intelligent Sensor

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Aiming at the problem of the fairness of the judgment results in the traditional basketball referee training and evaluation process affected by external factors, an intelligent system for training and assessment of basketball referees in sports events based on intelligent sensors is proposed. We collect the judged poses of basketball referees by wearing intelligent sensor devices, store the collected information in the database using the converter, and analyze the pose data with the quaternion pose solution method based on complementary filters. According to the comparator, the analysis result is compared with the standard judgment information, and the action is judged whether the action conforms to the basketball judgment rules of the sports event. The judge's action pose score is evaluated according to the judgment result, and the training assessment result is outputted. The results show that the system can clearly simulate the acceleration and pose angle data of the referee's complex actions, the recognition rate of various basketball penalty poses is high, and the error of the pitch, yaw, and roll pose calculations is small. The response time of this system is 4 ms, when the number of requests sent by the client is 200 which is unanimously approved by the referees.

1. Introduction

Due to basketball having attracted extensive attention from people from all walks of life all over the world, more and more attention has been paid to the fair and impartial adjudication of basketball events. Therefore, the judgment requirements for basketball referees are stricter [1]. In recent years, China has also paid more attention to basketball sports and invested a lot of money to train excellent basketball referees for basketball associations and sports colleges and universities, which has contributed to the development of basketball in China [2]. However, at present, the assessment of the professional ability of referees is not perfect. The requirements are for basketball referees to not only need to remember the judgment rules but also have professional referee quality [3]. At the same time, they have the ability to judge the trajectory and speed of basketball in time and accurately, so as to ensure the fairness and justice of the game results. Foreign basketball referee assessment methods ignore the due referee quality of referees, and the judgment method of referees mainly stays on man-made subjective consciousness. The evaluation methods of domestic basketball referees lack the judgment of motion direction and yaw angle in the process of basketball. Therefore, the main way of training and assessment of basketball referees still stays in the written way. This way cannot assess the judgment ability of referees in the field and cannot meet the needs of the development of modern basketball. Therefore, it is very necessary to continuously optimize the assessment method of basketball referee training. Many scholars have conducted relevant research on the assessment and training methods of basketball referees, but they have not achieved the ideal effect.

Relevant scholars have studied this and achieved some results. Xia et al. [4] proposed a training and assessment system based on the interactive simulation equipment of an urban rail operation. The system is based on the interactive simulation equipment of an urban rail operation, applies virtual reality technology, industrial automation technology, big data storage technology, and computer-aided behavior assessment technology and has all the functions of training practice assessment. This system can improve the efficiency of troubleshooting in real operating conditions, but the efficiency of training and assessment is low, and manual evaluation is relatively large. Sun and Wu [5] proposed an optimal pose estimation method for the Microelectromechanical System (MEMS) inertial system based on the indirect Extended Kalman Filter (EKF), deduced the linear motion features related to the state vector perturbation, designed the perturbed state equation, and adopted the standard linear Kalman filter for the perturbation The state and its covariance have been optimized and updated. Finally, the accelerometer output is used for observation, and the chain rule is used to complete the measurement matrix. This method can effectively reduce the impact of random drift on pose estimation, but the pose accuracy is poor. Wang and Zhu [6] proposed a multitarget visual tracking assessment system for basketball referees of different levels. This study takes basketball referees as an example and adopts the classic multitarget tracking MOT paradigm. This study was aimed at exploring the differences in the multiobjective visual tracking ability of basketball referees of different levels. This method can effectively track multiple targets but only considers the transmission of the basketball between passers, and the evaluation index is relatively single. Huo [7] proposed that the NBA referee credibility and authority system only pays attention to the referee's competition rules. Therefore, it is necessary to constantly improve the new basketball referee assessment and training method on the basis of learning from the experience at home and abroad. In recent years, with the wide application of intelligent sensors, various industries have achieved remarkable results by using the superior performance of sensors [8]. The advantage of the intelligent sensor is that it can capture information, data, and images and transmit them in real time and is less affected by external factors [9]. Therefore, this paper proposes an intelligent simulation system for basketball referee training and assessment in sports events based on intelligent sensors. The system can accurately identify the actions of basketball events, is not affected by human operation, and can accurately judge the movement speed and yaw angle of basketball, so as to ensure the fairness and justice of the judgment results and improve the public's cognition of the quality of basketball referees.

The contributions of this paper are as follows: (1) By wearing intelligent sensor equipment, the judgment pose of basketball referees is collected. (2) The converter is used to store the collected information in the database, and the quaternion pose solution method based on the complementary filter is used to analyze the pose data. (3) According to the comparison and analysis results of the comparator and the standard evaluation information, we judge whether the action conforms to the basketball evaluation rules of sports events. (4) We evaluate the score of the referee's action and pose according to the judgment results and output the training assessment results.

2. Design of Basketball Referee Training and Assessment Intelligent System

2.1. Overall System Structure. The designed sensing equipment is worn on the assessors, and the assessors are brought into the virtual basketball game through the sensing drive [10]; using the ability of the sensor to capture information, the pose and action of the referee are photographed and collected, and the collected information is connected to the database for storage through the converter. The collected information is analyzed based on the quaternion pose solution method of the complementary filter and compared with the standard evaluation information by the comparator [11, 12]. The interpreter is used to score the referee's actions and poses, and finally, the evaluation results are outputted through the output device. The hardware framework of the basketball referee training and assessment system is shown in Figure 1.

2.2. Sensor Driving Node Design. The intelligent sensing device mainly collects data according to the sensing drive [13], and Figure 2 describes the hardware circuit structure of the intelligent sensing device.

The intelligent sensing device is composed of a sensing driving part and a microprocessor, which are connected through a bus [14]. The intelligent sensing device is mainly responsible for collecting information and comprehensively sorting the collected information to obtain quaternion data. After the data is outputted, it is converted by a data converter and compared with the standard data [15]. As a key part of the whole system structure, the intelligent sensing device has high requirements for poses. Therefore, when designing the intelligent sensing device, it should meet its small features and be easy for the examiner to wear.

The microprocessor mainly uses the advantages of its various transmission means to make the information output timely and accurate. The microprocessor includes a controller to control the obtained data information, avoid the influence caused by the installation axis error of accelerometer and gyroscope [16], reduce the packaging space, and then output the sensing information. The main advantage of a triaxial magnetometer is that it occupies a small area and has a high synthesis effect [17]. With the Interintegrated Circuit (IIC) interface, it can maximize the accuracy of output information. The sensor driver is easy to operate and has low manufacturing cost, which reduces the complex effect of system construction to a certain extent.

2.3. Pose Calculation of Data Converter

2.3.1. Spatial Rotation Quaternion Method. The standard quaternion method has a small workload, fast response time, less relevance to microprocessors [18], and no repeated cycle mode. It can be used as a space full pose solution method [19]. Due to the convenient conditions of this method, the quaternion method is expressed as follows:

$$Q = q_0 + {q_1}^i + {q_2}^i + {q_3}^k. \quad (1)$$

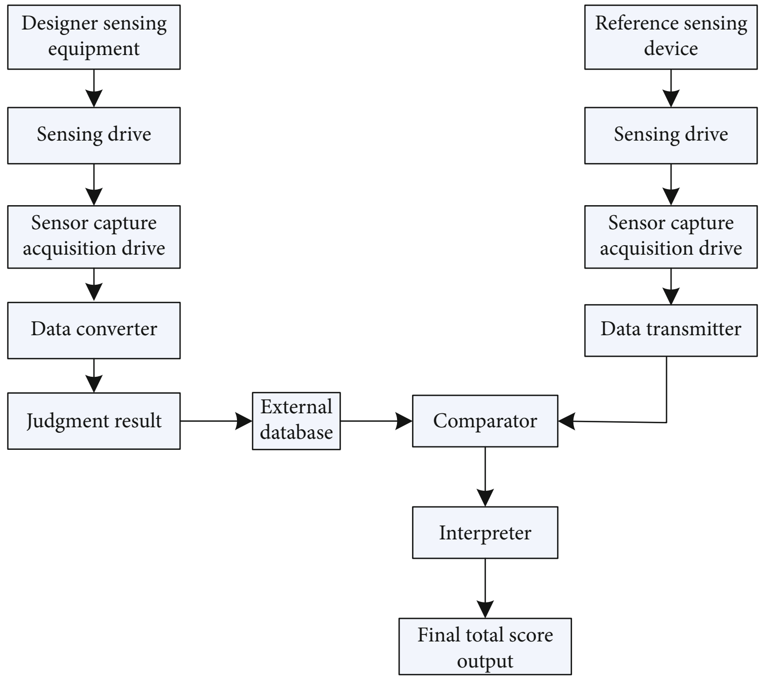

Figure 1: Overall system structure.

The size of the quaternion is expressed by the norm:

$$\|Q\| = {q_0}^2 + {q_1}^2 + {q_2}^2 + {q_3}^2. \tag{2}$$

The judgment method of the standardized quaternion depends on the value of $\|Q\|$. If the value is equal to 1, the quaternion is standardized [20]. The pose matrix is C_b^n, yaw angle is ψ, pitch angle is θ, and roll angle is φ. The equation of the pose matrix method is

$$C_b^n = \begin{bmatrix} \cos\psi\cos\varphi + \sin\psi\sin\theta\sin\varphi & \sin\psi\cos\theta & \cos\psi\sin\varphi - \sin\psi\sin\theta\cos\varphi \\ \cos\psi\sin\theta\sin\varphi - \sin\psi\cos\varphi & \cos\psi\cos\theta & -\cos\psi\sin\theta\cos\varphi - \sin\psi\sin\varphi \\ -\cos\theta\sin\varphi & \sin\theta & \cos\theta\cos\varphi \end{bmatrix}. \tag{3}$$

The pose matrix equation (3) can be expressed as

$$C_b^n = \begin{bmatrix} 1-2\left(q_2^2+q_3^2\right) & 2(q_1q_2 - q_0q_3) & 2(q_1q_3 + q_0q_2) \\ 2(q_1q_2 + q_0q_3) & 1-2\left(q_1^2+q_3^2\right) & 2(q_2q_3 + q_0q_1) \\ 2(q_1q_3 + q_0q_2) & 2(q_2q_3 - q_0q_1) & 1-2\left(q_1^2+q_2^2\right) \end{bmatrix}. \tag{4}$$

The quaternion differential equation of the pose matrix can be expressed as

$$\begin{bmatrix} q_0^+ \\ q_1^+ \\ q_2^+ \\ q_3^+ \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 0 & -\omega_x & -\omega_y & -\omega_z \\ \omega_x & 0 & \omega_y & -\omega_y \\ \omega_y & -\omega_z & 0 & \omega_x \\ \omega_z & \omega_y & -\omega_x & 0 \end{bmatrix}\begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{bmatrix}. \tag{5}$$

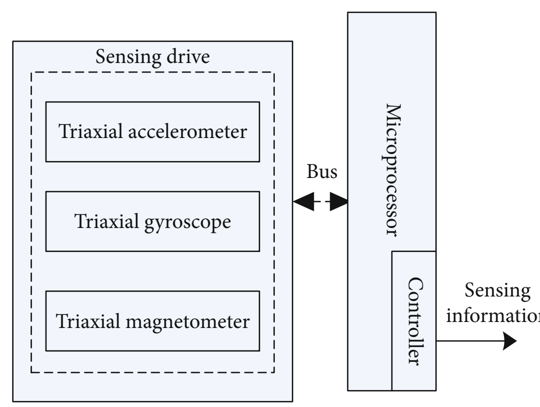

Figure 2: Hardware structure of intelligent sensing equipment.

The solution of the differential equation in equation (5) can be obtained in combination with the standardized quaternion initial value ${q_i}^{0^-}$ obtained in equation (6). After the obtained quaternion (q_0, q_1, q_2, q_3) is normalized, the normalized quaternion $({q_0}^-, {q_1}^-, {q_2}^-, {q_3}^-)$ for spatial rotation is obtained and can be used as the original value of the following differential equation (6) [21].

$$\begin{cases} |q_0| = \frac{1}{2}\sqrt{1 + T_{11} + T_{22} + T_{33}}, \\ |q_1| = \frac{1}{2}\sqrt{1 + T_{11} - T_{22} - T_{33}}, \\ |q_2| = \frac{1}{2}\sqrt{1 - T_{11} + T_{22} - T_{33}}, \\ |q_3| = \frac{1}{2}\sqrt{1 - T_{11} - T_{22} + T_{33}}. \end{cases} \tag{6}$$

Let T be a matrix; its symbol can be determined by sign (q_0). When $\|Q\| = 1$, we get a normalized quaternion; a standardized quaternion is obtained. Therefore, it can be seen that the quaternion q_i obtained from equation (6) is used for spatial rotation, and it should be standardized:

$$q_i^{0-} = \frac{q_i}{\sqrt{{q_0}^2 + {q_1}^2 + {q_2}^2 + {q_3}^2}}, \quad i = 0, 1, 2, 3, \tag{7}$$

where q_i^{0-} represents the initial value of the standardized quaternion.

2.3.2. Quaternion Pose Solution Method Based on Complementary Filter. The pose information is solved by an accelerometer and magnetometer. In different motion states, the calculation accuracy is high, but it is greatly affected by external factors and has poor flexibility [22]. A gyroscope can also calculate pose information with good flexibility, but due to the wide variety of calculation vectors, the accuracy of the data is not high. In order to obtain more accurate data information on the premise of flexibility, the information is obtained by fusing the sensor data, which mainly adopts the filtering algorithm. The Kalman filter has strong advantages in estimation [23], with large workload for matrix calculation and strong correlation constraints on the microprocessor. Compared with the complementary filter, the complementary filter has a faster processing speed and less computation when calculating the matrix and vector and does not consider the performance of the processor [24]. After random analysis, the complementary filtering algorithm is more suitable for pose calculation. The specific algorithm of pose solution is shown in Figure 3.

We describe the output vector of the accelerometer that terminates the motion under b by $a_b = (a_x^b, a_y^b, a_z^b)^T$. The component formed by acceleration g when affected by gravity is described by a_b; then, the detection vector of g is set to a_b.

Due to $[a_x^b, a_y^b, a_z^b]^T = C_n^b[0 \quad 0 \quad g]^T$, the third column vector of the latter is the measurement vector of gravity acceleration g, and the deviation of the measurement vector of detection vectors a_b and g is described by equation (8), which is the error e_{rra} of acceleration or the error $e_{rr\theta\varphi}$ of the pitch angle and roll angle.

$$e_{rra} = e_{rr\theta\varphi} = \begin{bmatrix} T_{31} \\ T_{32} \\ T_{33} \end{bmatrix} \times \begin{bmatrix} a_x^b \\ a_y^b \\ a_z^b \end{bmatrix}. \tag{8}$$

The magnetometer data processing is blocked, because the navigation coordinate system n is greatly affected by the local magnetic field, and the specific orientation of the magnetic field cannot be determined temporarily [25]. Therefore, the data obtained from coordinate system b must be studied and calculated.

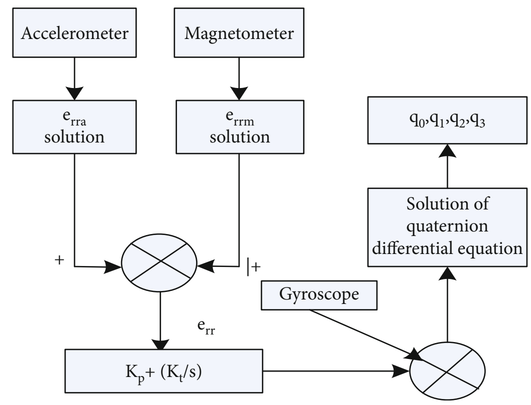

Figure 3: Pose solution process.

Figure 4: Motion image set.

Set in the carrier coordinate system b, the output vector of the magnetometer is $m_b = (m_x^b, m_y^b, m_z^b)^T$. Therefore, it is impossible to judge the area of the magnetic field, so it is subject to the same treatment:

$$m_b^- = \frac{m_b}{|m_b|} = C_n^b \left[m_x^{b-} \ m_y^{b-} \ m_z^{b-} \right]^T. \tag{9}$$

The observation vector m_b^- of the geomagnetic field is the component under b. To obtain the geomagnetic field data described in equation (10), it is necessary to convert m_b^- to the n system:

$$\left[h_x^n \quad h_y^n \quad h_z^n \right]^T = C_n^b \left[m_x^{b-} \quad m_y^{b-} \quad m_z^{b-} \right]^T. \tag{10}$$

The included angle between the Y-axis of the carrier and the due north direction is the yaw angle. (n_x^n, n_y^n, n_z^n) is used to describe the sorted local geomagnetic field data, and the precondition for sorting is that under the navigation coordinate system n. We set $n_x^n = 0$, $n_y^n = \sqrt{(h_x^n)^2 + (h_y^n)^2}$, $n_z^n = h_z^n$, and convert the data to the b system to obtain

$$\left[b_x^b \quad b_y^b \quad b_z^b \right] = C_n^b \left[n_x^n \quad n_y^n \quad n_z^n \right]^T. \tag{11}$$

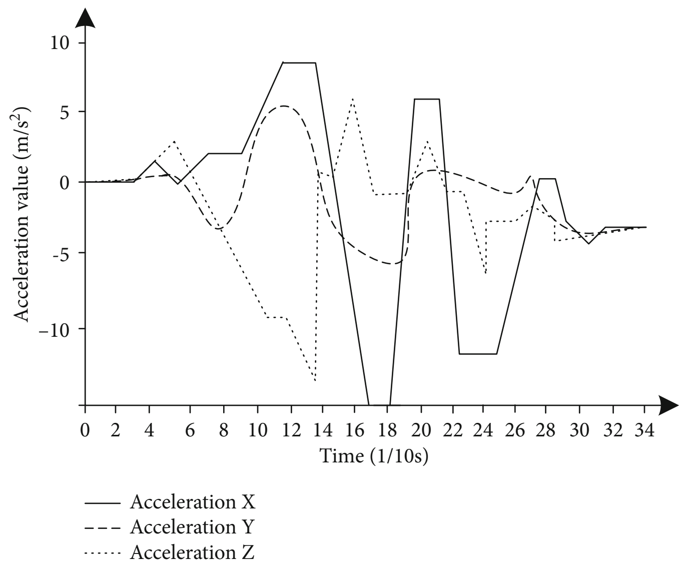

Figure 5: Acceleration data of complex action.

Through the cross-multiplication of geomagnetic measurement vector and observation vector in carrier coordinate system b described in equation (12), we obtain e_{rrm} and $e_{rr\psi}$:

$$e_{rrm} = e_{rr\psi} \begin{bmatrix} b_x^b \\ b_y^b \\ b_z^b \end{bmatrix} \times \begin{bmatrix} m_x^{b-} \\ m_y^{b-} \\ m_z^{b-} \end{bmatrix}, \quad (12)$$

where $\left(b_x^b, b_y^b, b_z^b\right)^T$ is used to describe the geomagnetic field measurement vector.

The pose angle error of the system is

$$e_{rrm} = e_{rr\psi} = e_{rr\theta\varphi}. \quad (13)$$

Correction of the gyro data by error is

$$\delta = K_p \cdot e_{rr} + K_t \int e_{rr}, \quad (14)$$

$$\omega = \omega_b + \delta, \quad (15)$$

where the adjustment quantity of error is described by δ; K_p and K_t are the adjustment coefficients. The output value of the gyroscope in the carrier coordinate system is ω_b, and ω is the adjusted gyroscope value.

3. Experimental Results and Analysis

3.1. Data Sets. In order to verify the effectiveness of this system, a basketball game simulation environment was built by MATLAB simulation software to verify the intelligent simulation effect of the basketball referee training and assessment of this system; according to the pose recognition features of the system, the recognition accuracy, judgment error rate, and response time are tested. The results provide convenience for the theoretical assessment of basketball referees. The experimental data sets are the Kaggle data set and the Google Trends data set. Some images in the dataset are shown in Figure 4.

In the process of training and testing long short term memory (LSTM) network, the learning rate of the network is 1e-3 and the batch size is 128; that is, 128 feature vectors are input each time. The input feature of the network at each time is that the dimension is 4096 and the step size is 16; that is, one result is predicted every 16 frames. Among them, the number of nodes in the middle hidden layer is 256, the number of layers of LSTM is 1, and the number of categories of the last output event classification is 5, corresponding to 5 categories: 3-point shot, free throw, other 2-point shot, layup, dunk, and snatch.

3.2. Experimental Indicators

3.2.1. System Data Simulation Effect. The more accurate the acceleration data and pose angle data of complex actions are, the more obvious the pose features are recognized. On the contrary, the worse pose features are recognized.

3.2.2. System Recognition Rate. The higher the recognition rate of the intelligent simulation system, the better the recognition effect of the system. On the contrary, the lower the recognition rate of the assessment intelligent simulation system, the better the recognition effect of the system. The calculation equation of recognition rate is

$$S_r = \frac{t_r}{D_s} \times 100\%, \quad (16)$$

where S_r is the recognition rate of the basketball assessment intelligent simulation system. t_r is the pose accurately recognized by the basketball assessment intelligent simulation system. D_s is the number of all poses of the basketball assessment intelligent simulation system.

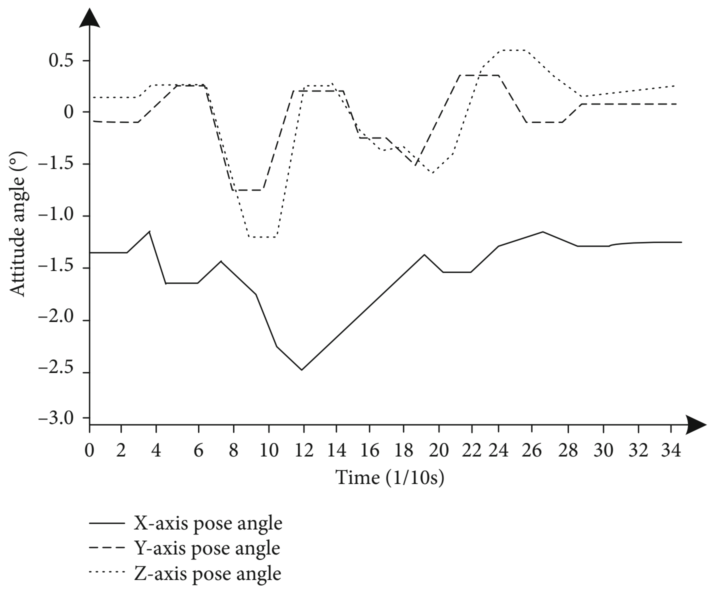

Figure 6: Pose angle data of complex action.

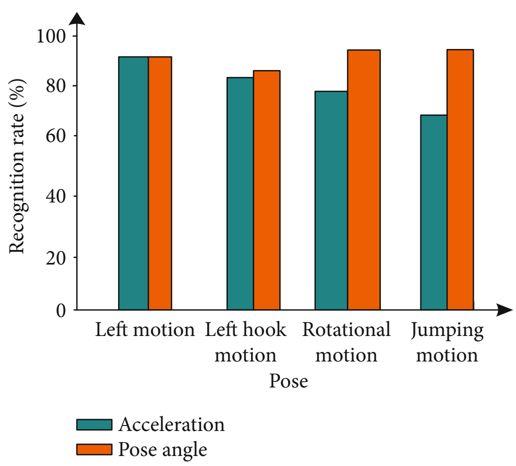

Figure 7: Comparison of recognition rates of different pose actions.

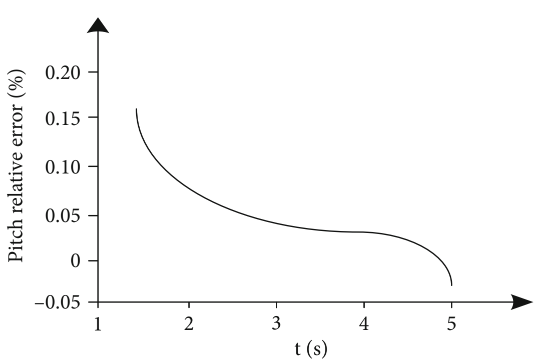

Figure 8: Pitch relative error.

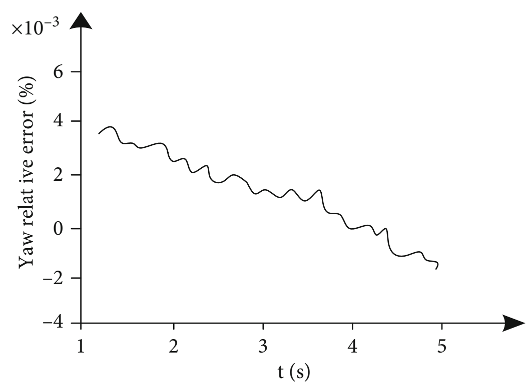

Figure 9: Yaw relative error.

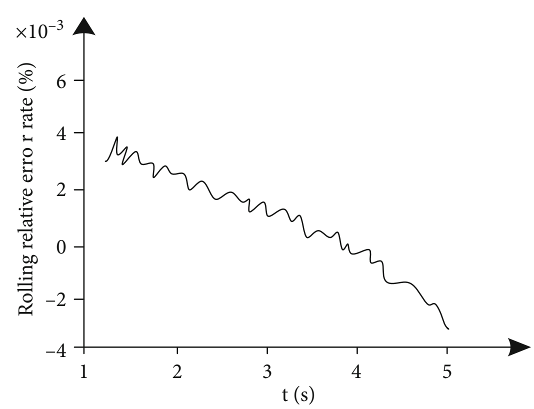

Figure 10: Rolling relative error.

3.2.3. Pose Solution Effect. The smaller the pitch, yaw, and rolling pose solution error, the better the pose solution effect. On the contrary, the larger the pitch, yaw, and rolling pose solution error, the worse the pose solution effect.

3.2.4. System Response Time. The shorter the system response time, the higher the system processing efficiency. On the contrary, the longer the system response time, the lower the system processing efficiency.

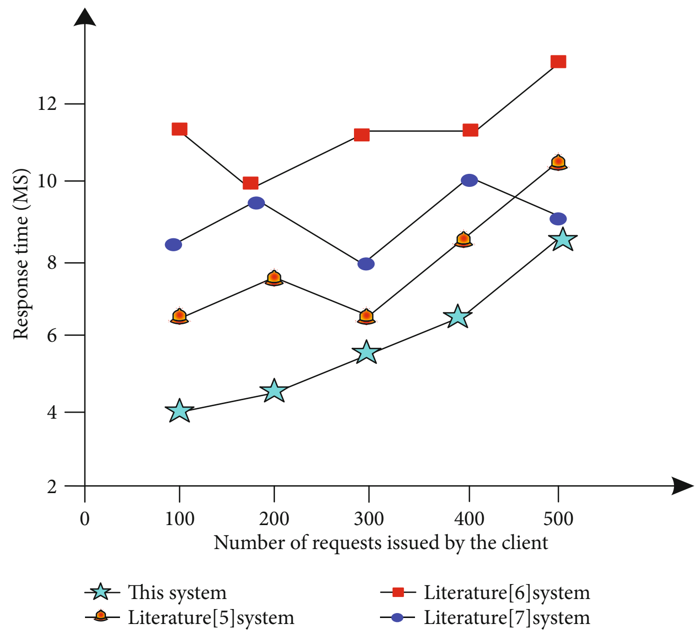

Figure 11: Comparison of response time.

$$h_t = \frac{(t_2 - t_1)}{t_1 + t_2}, \tag{17}$$

where h_t is the response time of the basketball assessment intelligent simulation system. t_1 is the time when the basketball assessment intelligent simulation system starts processing. t_2 is the time when the processing of the basketball assessment intelligent simulation system is completed.

3.2.5. System Use Effect. The higher the degree of satisfaction with the use of the intelligent simulation system, the better the effect. On the contrary, the lower the degree of satisfaction with the use of the intelligent simulation system, the worse the effect.

3.3. Results and Discussion. The poses of referees in basketball games affect the fair judgment of the game. The referee can judge whether the basketball player has committed a foul through a simple pose, and the simple action acceleration data can well show the specific action behavior features. However, the complex judgment pose action includes not only the flexion of the finger but also the swing of the arm, which is difficult to recognize. Therefore, in order to verify the ability of the system to recognize the features of this complex action, the acceleration and pose angle are compared. The specific results are shown in Figures 5 and 6.

It can be seen from the Figure 6 that the system in this paper can clearly simulate the acceleration data and pose angle data of complex actions, accurately identify the pose features, and describe the changes of pose features in different time periods.

In order to verify the recognition rate of basketball referee's action data by this system, a set of experimental analyses is carried out. By selecting four different action data of basketball players during the game, each action data includes acceleration and pose angle, and the recognition rate is shown in Figure 7.

As can be seen from the data comparison diagram in Figure 7, there is no significant difference in the recognition rate of acceleration and pose angle compared with relatively simple pose actions such as left motion and left hook motion. However, for complex actions such as rotation, the recognition rate of pose angle data in this system is significantly higher than that of acceleration data, but the recognition rate of the two data under different pose actions is more than 75%. Therefore, the system in this paper has better pose recognition effect, and the recognition effect of the pose angle is better.

In order to verify the effectiveness of the pose solution algorithm in the basketball game, the motion of basketball in the basketball game is simulated. This paper mainly tests the analytical error of basketball from three angles: pitch, yaw, and rolling. The relative errors of the three angle analysis results are shown in Figures 8–10.

It can be seen from the preceding figures that the error of the pose solution for the pitch, yaw, and rolling is basically in the order of 10-3%, which proves that the deviation of the system in this paper for basketball direction analysis is small. The large fluctuation of yaw and rolling is due to the false error when the pose angle is equal to 0, which cannot constitute the influencing factor for the referee to judge the game. It is proven that the system in this paper can have a good analytical effect on the trajectory and direction of basketball, and the error rate is low, which verifies the effectiveness of the system method in this paper.

In order to verify the response speed of this system to the transmitted data, this system is compared with the inertial

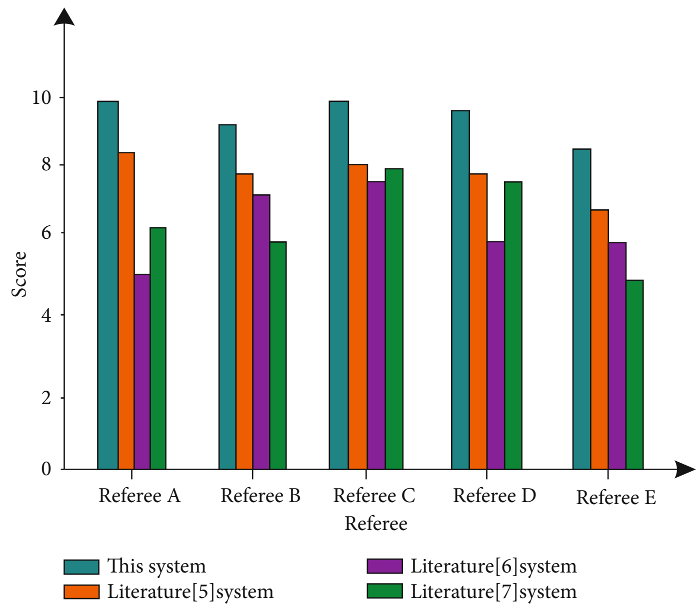

Figure 12: Scoring results.

system (literature [5] system), multitarget visual tracking system (literature [6] system), and NBA referee credibility and authority system (literature [7] system). The response time comparison results are shown in Figure 11.

As can be seen from Figure 11, when the number of requests sent by the client is 200, the response time of the system in literature [5] is 7.3 ms, the response time of the system in literature [6] is 10 ms, and the response time of the system in literature [7] is 8.9 ms. The system response time is 4 ms; with the increasing number of requests sent by the client, the response time of this system in each stage is lower than that of other systems, and the fluctuation is small. The fluctuation of other literature systems is more obvious and does not fluctuate upward according to the change of the number of requests. Therefore, the stability is poor. It is proven that the system has fast response speed and good stability to the data transmission of basketball referees and can avoid the impact of data delay on the fairness of referees to a certain extent.

In the experiment, five basketball referees were selected to evaluate the effects of the four systems. The scores ranged from 1 to 10 points. The scoring results are shown in Figure 12.

According to Figure 12, it can be seen that the lowest score for this system is not less than 9, and the highest score for other systems is not more than 8. The score for the literature [5] system is relatively high. However, the score of this system is still not reached, indicating that there is still a certain gap between the system of literature [5] and the system of this paper in some aspects, which caused the referees to not score enough points. This proves that this system has more advantages than other systems and is highly satisfied with the effect of this system. This system provides a more convenient and fairer training and evaluation simulation platform for basketball referees.

4. Conclusions

In recent years, the emergence of intelligent sensors in life at home and abroad provided a good environment for the wide application of intelligent sensors. Aiming at the imperfect problem of basketball referee evaluation system, this paper proposed an intelligent simulation system for basketball referee training and evaluation in sports events based on the intelligent sensor. The system proposed in this paper breaks the traditional idea that the assessment can only be carried out in written form and improves the quality of the assessment of basketball referees to a great extent, which lays a foundation for the assessment of basketball referees in the future. The following conclusions are obtained by experiments: (1) In this study, the system can accurately recognize pose features and describe the changes of pose features in different time periods. (2) The recognition rate of the pose angle data in this system is significantly higher than that of acceleration data. This system has better pose recognition effect, and the recognition effect of the pose angle is better. (3) Compared with other systems, this system has more advantages and is highly satisfied with the effect of this system. This system provides a more convenient and fairer training and evaluation simulation platform for basketball referees. The application of intelligent sensor in the basketball referee training and assessment system of sports events has just started. On this basis, how to combine specific applications in the multiangle and multidirectional enrichment of the assessment system to solve the problem of unfair judgement results due to imperfect assessment is worthy of further study.

Data Availability

The data that support the findings of this study are openly available in the Kaggle data set and Google Trends data set.

Conflicts of Interest

The authors declare that there is no conflict of interest with any financial organizations regarding the material reported in this manuscript.

References

[1] W. Pengyu and G. Wanna, "Image detection and basketball training performance simulation based on improved machine learning," *Journal of Intelligent and Fuzzy Systems*, vol. 40, no. 2, pp. 2493–2504, 2021.

[2] J. Cho and M. Lee, "Building a compact convolutional neural network for embedded intelligent sensor systems using group sparsity and knowledge distillation," *Sensors*, vol. 19, no. 19, article 4307, 2019.

[3] G. B. Sinnapolu and S. Alawneh, "Intelligent wearable heart rate sensor implementation for in-vehicle infotainment and assistance," *Internet of Things*, vol. 12, no. 41, article 100277, 2020.

[4] X. Xu, Y. Chen, Z. Liu, Y. Sun, L. Zhou, and J. Antonio, "The value of intelligent ultrasound sensor used in the measurement of fetal hemodynamics and evaluation of health factors," *Measurement*, vol. 158, no. 11, article 107699, 2020.

[5] S. Wei and W. Jiaji, "Optimal attitude estimation of MEMS inertial system based on indirect EKF," *Journal of Sensors*, vol. 32, no. 1, 85 pages, 2019.

[6] W. Tianyang and Z. Congqing, "Empirical study on multi-objective visual tracking of basketball referees at different levels," *Journal of Tianjin Institute of Physical Education*, vol. 35, no. 6, pp. 703–707, 2020.

[7] H. Chuansong, "On the origin of the NBA referee's credibility from the social perspective," *Journal of Nanjing Institute of Physical Education (Social Science Edition)*, vol. 2, no. 2, pp. 82–87, 2019.

[8] Y. Li, Y. Cai, R. Malekian, H. Wang, M. A. Sotelo, and Z. Li, "Creating navigation map in semi-open scenarios for intelligent vehicle localization using multi-sensor fusion," *Expert Systems with Applications*, vol. 184, no. 3, article 115543, 2021.

[9] G. Liu and X. Li, "Multidimensional heterogeneous medical data push in intelligent cloud collaborative management system," *Complexity*, vol. 2020, Article ID 7574609, 14 pages, 2020.

[10] M. Kopczynska, S. Smits, R. Hopps et al., "Assessment of technical parameters and skills training to inform a simulation-based training program for semi-automated robotic colonoscopy," *Endoscopy International Open*, vol. 7, no. 1, pp. E9–E14, 2019.

[11] Y. Ma, Y. C. Luan, W. G. Zhang, and Y. Q. Zhang, "Numerical simulation of intelligent compaction for subgrade construction," *Journal of Central South University*, vol. 27, no. 7, pp. 2173–2184, 2020.

[12] X. Li, J. Wei, and H. Jiao, "Real-time tracking algorithm for aerial vehicles using improved convolutional neural network and transfer learning," *IEEE Transactions on Intelligent Transportation Systems*, pp. 1–10, 2021.

[13] L. Grainger, K. Amin, and D. Watkins, "Simulation-based training to teach nurses skills in falls assessment and prevention," *Nursing Older People*, vol. 31, no. 1, pp. 36–38, 2019.

[14] C. W. Yang, S. C. Ku, M. H. M. Ma, T. S. Chu, and S. C. Chang, "Application of high-fidelity simulation in critical care residency training as an effective learning, assessment, and prediction tool for clinical performance," *Journal of the Formosan Medical Association*, vol. 118, no. 9, pp. 1347–1355, 2019.

[15] E. Yuen, A. K. Zaleta, S. McManus et al., "Unintentional weight loss, its associated burden, and perceived weight status in people with cancer," *Supportive Care in Cancer*, vol. 28, no. 1, pp. 329–339, 2020.

[16] J. Sasadai, N. Maeda, R. Shimizu et al., "Analysis of team-sport wheelchair falls during the Rio 2016 Summer Paralympic Games: a video-based cross-sectional observational study," *BMJ Open*, vol. 10, no. 3, article 033088, 2020.

[17] D. G. Özkan, R. Pezzetta, Q. Moreau, A. M. Abreu, and S. M. Aglioti, "Predicting the fate of basketball throws: an EEG study on expert action prediction in wheelchair basketball players," *Experimental Brain Research*, vol. 237, no. 12, pp. 3363–3373, 2019.

[18] J. Jacobsen, "Competition mounts for sports drinks," *Beverage Industry*, vol. 110, no. 5, pp. 16-17, 2019.

[19] G. Nagarajan, R. I. Minu, and A. Jayanthila Devi, "Optimal nonparametric Bayesian model-based multimodal BoVW creation using multilayer pLSA," *Circuits, Systems, and Signal Processing*, vol. 39, no. 2, pp. 1123–1132, 2020.

[20] C. Salas, P. Sintes, J. Joan, D. Urbano, J. Sospedra, and T. Caparros, "Conservative management of femoroacetabular impingement (FAI) in professional basketball," *Apunts Sports Medicine*, vol. 55, no. 205, pp. 5–20, 2020.

[21] L. Wu, Z. Yang, J. He et al., "Ontology-based global and collective motion patterns for event classification in basketball videos," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 30, no. 7, pp. 2178–2190, 2020.

[22] J. B. Bolen, J. Rezek, and J. D. Pitts, "Performance efficiency in NCAA basketball," *Journal of Sports Economics*, vol. 20, no. 2, pp. 218–241, 2019.

[23] X. Ma and X. Li, "Dynamic gesture contour feature extraction method using residual network transfer learning," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 1503325, 11 pages, 2021.

[24] F. de Jong, D. Driesnack, A. Mason, M. Parmentier, P. Sunna, and S. Thompson, "European athletics championship: lessons from a live, HDR, HFR, UHD, and next-generation audio sports event," *SMPTE Motion Imaging Journal*, vol. 128, no. 3, pp. 1–10, 2019.

[25] C. Peilin, Z. Zahe, L. V. Pin, and H. Bin, "Adaptive error quaternion unscented Kalman filter for attitude calculation of four rotor aircraft," *Journal of Xi'an Jiaotong University*, vol. 53, no. 3, pp. 97–102, 2019.