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Innovative Application of Computer Vision and Motion Tracking Technology in Sports Training

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Abstract

The use of cutting-edge technology has resulted in a significant enhancement in athletic training. Computer vision and motion tracking are very important for enhancing performance, reducing the risk of accidents, and training in general. Some computer vision algorithms investigate how a sportsperson moves when competing or practising. It is possible that coaches who continuously evaluate their players' posture, muscle activation, and joint angles would have a better understanding of biomechanical efficiency. It is possible to generate performance measurements from the real-time surveillance of athletes while competing in sports. Through the use of computer vision, it is possible to identify acts that might be hazardous. Notifications are given to coaches if there is a deviation in the form of an athlete, which enables them to address the situation as soon as possible. The three variables that these sensors monitor are the direction, speed, and acceleration. Athletes can encounter realistic environments thanks to the integration of motion tracking with virtual reality. One may use the feedback loop to increase their spatial awareness and decision-making ability. Augmented reality allows for enhancing an athlete's eyesight by providing them with real-time data while practising. Last but not least, the use of computer vision and motion tracking is bringing about a significant improvement in the sporting training process. Through collaborative efforts, researchers, athletes, and coaches can accelerate humans' performance to levels that have never been seen before.

Keywords: AR, VR, Athletes, Sports

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1. Introduction

Sports are enjoyed by people worldwide. Every year, many individuals from all walks of life participate in various forms of athletic competition. Yet, only those competitors who believe in what they're doing are chosen. The ancient adage says, "Determination is the key to success." It certainly applies to athletes; the only way to reach one's goals is to work hard and stay focused [1]. Athletes in any sport may now be easily trained and improved with modern technologies. In the past few years, the recognition of action by athletes has been a prominent field of research. An athlete's success in a given sport may be predicted by studying his body language and how he stands and moves. Research into the best ways to estimate the action poses of athletes is a new field [2].

Currently, the majority of them rely on conventional image processing techniques. Consequently, various sportsmen are the primary users of the centered-around technology approach [3]. Virtual and augmented reality, artificial intelligence, and information technology are the most prevalent types of systems powered by technology used in athletics. Contemporary technologically based software is used in all designs. The main goal of this software is to develop and improve sports on a global scale. Regarding computer vision-based sports technology, there are two main principles to remember [4]. To start, there is virtual reality. Virtual reality is all about using images to aid in physical education instruction. Athletes may benefit from

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visual learning when it comes to mastering game strategies. Research on images is the most prevalent in the sports science area. Athletes and trainers have been interested in imaging because of its benefits and the time it saves [5].
Virtual reality's primary function in sports education is to help athletes hone three crucial skills. Athletes need to learn how to evaluate their performance first. The second type is the improvement of stimuli, and the final one is the use of visual enhancements in training, often known as virtual training, for athletes. All three factors are crucial for a sporting athlete to train effectively using VR [6]. Many industries have found uses for virtual reality (VR) technology. VR technique has many applications in the sporting world, including creating an artificial playing field and a three-dimensional simulation of games. Athletes need deft racquet handling skills and excellent motor coordination to excel at this technically demanding sport. Currently, this game's virtual reality research and development is confined to 2D/video analysis [7].
Modern mobile AR and VR technologies hold the key to drastically alter many facets of our current way of life. Since mobile augmented reality aims to accurately position and present virtual objects in real-world settings, mobile computing must be used to determine the user's location and what they are looking at. On the contrary, together, mobile VR enables various user-to-virtual environment engagements and conversations [8]. There are currently three main groups into which motion tracking techniques for mobile AR/VR can be divided: marker-oriented, model-driven and marker-free-oriented. Only with specific prior knowledge about the area can 6-DoF tracking be accomplished using marker-oriented or model-based approaches. However, markerless-based motion tracking can function in unsupervised settings. Because of this, markerless tracking will likely become the standard for mobile AR/VR down the road [9].
The reliability and practicality using real-time 6-DoF indicators require more research, with less motion tracking for mobile AR/VR, because of the high computational needs and unpredictability settings. The lag and instability between successive arrival postures would ruin the consumer's knowledge, particularly in the virtual reality scenario [10]. VR opens the door to the possibility of creating training experiences that are both realistic and immersive. Rather than basic simulations, these settings are meant to reflect the precise circumstances of a real-life game or training situation. Consequently, virtual reality (VR) is acknowledged as a fully immersive setting that surpasses just simulation [11].
Athletes now have an unprecedented chance to perfect their skills and learn everything about their performance in a risk-free setting, thanks to the transition from replication to near-reality. Augmented reality (AR) is a technical development that, like virtual reality (VR), provides immersive experiences by further merging the real and virtual worlds [12]. By superimposing digital data on top of a live sporting event, augmented reality (AR) may turn the field into a dynamic, interactive platform for in-the-moment performance evaluation. An athlete's technique, location, and motions may be evaluated using this technology and given quick feedback, allowing for fast modifications and improvements [13].
Such real-time feedback systems allow for faster learning and mistake correction, leading to better performance. The use of AR in strategic planning is also showing potential. For more in-depth explanations of formations and tactics, coaches may use computerised visuals superimposed over the playing surface [14]. Players' comprehension and strategy execution may be improved with this visual aid. This technology makes it easy for coaches, players, and analysts to comprehend and act upon performance measurements by transforming complicated data into visually appealing representations. Improved informed decision-making is facilitated by this improved information transmission, which leads to a better knowledge of achievement patterns, trends, and possibilities for development [15].
This work is the first to tackle the issues of visual-inertial fusion turbulence and a latency period in mobile AR and VR, particularly concerning the increased frame-rate needs of mobile VR. Here are the key points from the article:

- Developing motion tracking technology for use in athletic training via the use of virtual and augmented reality
- Assessing the efficacy of VR and AR in achieving precise motion tracking for athletic training
- Using the concept of calculating the resemblance of actions using the Euclidean distance that exists between two vectors, this research aims to enhance the algorithm's effectiveness.

In segment 2, related work has been discussed. In segment 3, a motion tracking system based on VR and AR has been suggested. In segment 4, results from experiments were presented. In segment 5, final considerations and future preparations have taken place.

2. Literature Review

Lijin Zhu [16] presented a method for evaluating motion assistance that uses deep learning algorithms to identify human posture. The system comprises a common motion database, supplementary teaching, and overall assessment. The individual in charge of the system can personalise the predefined motion database and include the supplementary educational method. The data is easily digestible by the teachers, and their actions can be contrasted with the actions of ordinary consumers. Teachers are given The system's general evaluation element can recognize and present videos, thereby creating a comprehensive teaching platform. A virtual environment is another option for taking exams. The total assessment system may detect and filter video files to provide trainers with an adaptive teaching system.
Peng Wang [17] proposed sports training activity detection using a deep learning system. To identify the motion

samples, a deep learning approach is suggested that relies on the motion properties of nearby joints. To address the model’s inadequacies, we integrate spatial settings to increase the algorithm's identification reliability and decrease the model’s typical error. The research potential and practical relevance of the deep learning approach are highlighted following a thorough examination of the associated recognising motion tasks. The current state of deep learning research is presented about the data mode employed, laying the groundwork for subsequent work on identifying actions using local motion distinctive characteristics.

Naichun Gao [18] discussed that A hidden Markov model that uses artificial intelligence and computer vision is built to capture video footage and recognise the process of landing and take-off motions as well as the badminton court serving motions of a group of players during a training session. The frequency of mistakes and total error count for the landing leap action were determined using a Bayesian classification method applied to the collected data from the training exercises. Deep learning training consists of two phases: To train a neural network, one single neuron is constructed in the layer following the layer. After each layer has been taught, the network is fine-tuned using a wake-sleep procedure. According to the results, athletes often make knee valgus mistakes when landing a jump.

Wenxin Du [19] initiated computer vision and artificial intelligence technologies to build a model for identifying when an athlete is doing wrong using a dual channel 3D convolutional neural network (CNN). Accurate detection of athletes’ wrong behaviours was accomplished by employing inter-framed differential knowledge, which, when combined with black-and-white film, might indicate significant shifts in the mobility of the players. The simulation findings demonstrate that this technique’s capacity for recognition gradually declines with an increase in the number of technical faults in sports. The experiment's findings demonstrate that the proper rate progressively declines as the number of incorrect actions increases.

Pitre C Bourdon et al. [20] considered Experts in the field regularly assess training loads using interdisciplinary methods, and there has been a remarkable surge in empirical and practical research devoted to finding the most effective ways to collect and analyse data. The area has grown so rapidly in the last few years that it has spawned new companies focused on creating innovative models to better understand and mitigate the risks to athletes’ physical and mental well-being caused by various environmental factors. Assessing both internal and outside loads has a lot of established ideas and procedures, and top sports have a long history of collecting and analysing data on training and competition loads. The team backing the athlete must be aware of each variable's advantages and disadvantages in different sport-specific settings.

Muhammad Talha [21] analysed the research on simplifying sports training using 3D modelling and motion capture technology. Examine the studies that have examined the possibility of employing motion capture and 3D modelling to streamline athletic training. The investigation used a clever PLS Algorithm model, segmented evaluation, indication correlation, and significant analysis as part of the statistical software to decide the research. An econometric framework including dependent and independent variables is detailed in the presented study. A comprehensive study found that the use of 3D modeling and technology that captures motion enhanced athletic instruction. Motivating the players to give their all is the goal of this outstanding criticism. Thanks to electronic technology timers, a big issue with the timing and results of different sports has been resolved in the sporting world.

Jie Liu et al. [22] presented An overarching framework for a knowledge-based coaching system (KBCS) that would enable intelligent and autonomous sports training by combining human-computer interaction (HCI) technology with sports knowledge. Next, the KBCS is used to practice table tennis. Using algorithms for sporting feature calculations, motion identification, and table tennis striking stage division, one may statistically assess the performance of athletes. The results show that when comparing the beginning and ending frames of the unnoticed section with the market segment, the velocity computed by the location after combining shows greater continuity. The experimental findings demonstrate that the level distribution computed by the system for the three participants corresponds to real-world circumstances regarding the standard of motion and the quality of the returned ball. This proves that the suggested KBCS and methodology work in a small number of cases, which improves the accuracy of posture rehabilitation for athletes in their respective athletic training.

Zahari Taha et al. [23] proposed developing a new way to train using technology that might improve the athlete. Current motion tracking methods may provide precise and dependable tracking data, yet many athletes cannot afford or use them due to their intricate design and high product cost. This study aims to evaluate Kinect Technology in relation to an independent measurement unit (IMU). In this study, we tracked the kinematics movements of the arms from wrists to the upper arm using Kinect motion tracking and compared the results to those from a cheap inertial measurement unit (IMU). The results were deemed encouraging, and it is crucial to allow pattern recognition of different badminton swings in the subsequent phase of inquiry. Additionally, we will examine the effects of various equipment placement and installation options to design the VR for the badminton training system.

Banoth Thulasya Naik et al. [24] discussed an extensive examination of sports footage for various uses: advanced analysis, including player recognition and categorisation, monitoring and forecasting the trajectories of athletes or balls, identifying team strategy, and categorising different sporting events. Additionally, the study delves into published studies in several sports-related application-specific tasks, expressing the current researcher’s thoughts on them. Several publicly accessible datasets about a certain sport have been covered since there is a vast amount of room for study in sports to apply computer vision methods to distinct sports. Embedded systems, graphics processing unit (GPU) workstations, and artificial intelligence (AI) applications in sports vision are reviewed in this study. The paper concludes by outlining the future of visual identification in sports, including potential obstacles, research areas, and trends.

Kristina Host and Marina Ivasic-Kos [25] presented One use of HAR in sports performance monitoring, which involves detecting the player, following their motions, identifying the activity, comparing different actions, comparing different types of acting performances, or automatically analysing statistics. Various activities can take place on a sports field, including a series of physical motions that a player might execute to accomplish a goal or interact with other people or things. This motivates the suggestion of an innovative action classification scheme that considers interaction levels, complexity, and performance. This study provides a summary of HAR applications in sports, focusing on Computer Vision as the key contribution, and uses prominent publically accessible datasets for this purpose.

According to the results, several issues with the current approaches hinder student happiness and academic achievement. The third portion provides a quick overview of the motion tracking system concept based on virtual and augmented reality.

3. Proposed Work

Computer vision is a non-destructive assessment method that is both rapid and affordable. Incredibly a significant subfield within the larger image processing and motion recognition field. Computer vision primarily aims to mimic the visual traits of human beings and other living creatures using computers and other intelligent technologies. Research into artificial intelligence and the ability of computers or robots to comprehend their environment has led to the development of industrial machine vision systems, which can speed up processes such as checking bottles on the assembly line. It may use the footage as an instrument to analyze the image and extract 3-D information about the relevant environment. It gets its information from the submitted picture's description and context, then uses that information to analyze the photograph's unique properties and create a digital copy of the content.

As an alternative to the human brain, computer vision employs various video image capture technologies to simulate the human visual organs, taking in visual information as input and processing it digitally. Before it reaches its ultimate goal, computer vision research has a long way to go: teaching computers to autonomously adapt to their environments so that they can detect things and environments in the same way humans do. In order for computer vision research to reach its end goal, an optical system that is both visually sensitive and capable of intelligently completing tasks must be developed. In a kinetic function, the matter to be clustered is seen as an ensemble, and the quantity of energy between its parts represents the amount to which objects vary. Reclassification of the system is necessary when the energy level is high enough for the items to create a new class.

3.1. Developing a Computer Vision-Based System for Digital Coaching.

Sportsmen should peruse the reference library in search of a certain educational goal. After that, they choose the typical exam with a certain difficulty level. All activities are initially set at a difficult level to accommodate their ability levels. The system may determine optimal exercise group and difficulty based on athletes' ability levels, reference goal levels, written material, and the significance of indicators.

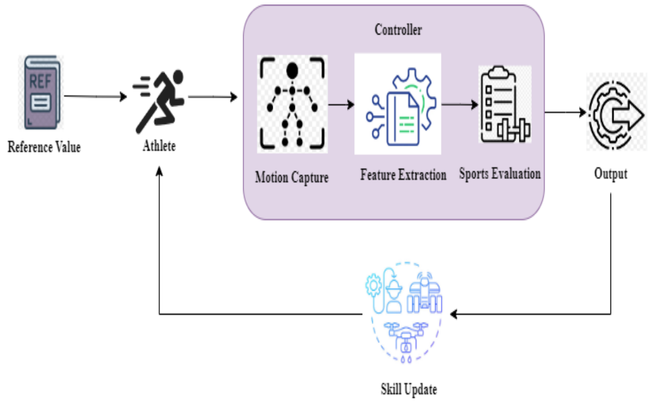

Figure 1. Methods for Sports Coaching System

After making adjustments regarding difficulty progression and applicable skill metrics for the task group, the software is going to select fresh workout material to provide to participants whose real-time performance satisfies the criteria for that particular workout. In any other case, it will compare the present athlete's performance to the recorded functionality inside the collection of commands, choose the direction that is most similar to providing input given to sportsmen, and adjust the choice of authority based on the evaluation effect. Athletes' skill levels must be very close to the reference levels as a prerequisite for ending participatory training. If athletes feel that the equipment refreshes their level of proficiency incorrectly or causes a change in their abilities during private practice, they may calibrate particular skill indication readings using traditional evaluations. After that, the program will adjust the training based on the updated performance thresholds. Figure 1 is a flow diagram depicting the whole training process.

Digital sports training tracks players' positions and updates their gear using motion capture and other technologies. The data collected may then be used to assess the players' most recent performance in sports and tailor their training programs appropriately. Digitalisation of training content/instruction creation, digitalisation of athletic performance data, and digitalisation of sports knowledge expression are all part of this. A coach's subjective experience may be expressed explicitly as words or statistics via digitalising sports knowledge representation. When sporting events digitise their performance records, they preserve the primary sports data used to calculate indicators based on the skill indications put to the test. The level of expertise needed by athletes in various sports and the specifics of the information that must be recorded in a precise and unique manner vary greatly. The human body's rotational axis, limb length, joint angle, workout duration, and exercise duration are all motion capture components. Table tennis, tennis, and other small-ball sports use data tracking of the ball's trajectories and the racket's acceleration, whereas rowing sports use data tracking of the boat's hull displacement.

Archive of references for athletes to pick from, T keeps track of the different skill indicator scores of elite athletes or the standards of a certain level. The acquired skill level and practising material are linked. It is recommended that each skill level be fine-tuned to the maximum extent feasible to strengthen the contrast between various practice groups. This will ensure that the association between each practice group and skill level is credible. Regardless of the sport, you may find an activity in the activity Library X. Group and difficulty levels apply to all training material. In addition to dynamic practice, the testing library includes standard exams of varying difficulties; however, the information that differs from the interaction practice is stated individually. All the instructional training-related reinforcement commands are stored in the instruction library C, and each instruction is separate from the others. Generating commands during training is likewise an optimisation process that happens gradually. By comparing results from other sports, we can narrow the search area and increase the optimum feedback command's resolution performance.

3.2. Motion capture systems

Motion capture technology includes the method that uses technology to analyse the position and movement of different objects being studied. When it comes to tracking the motion of an item, this technology is at the cutting edge. Almost every industry can benefit from this technology. The ability to see things in motion is a feature of many computer control systems. An exciting new area of study is the prediction of the action stance of athletes. To be more specific, a recreation's evaluation method interacts with professional coaches to convert intangible, individual assessment concepts into measurable, objective performance metrics. Motion capture technology allows for collecting a great deal of unique sports data. Accurate sports assessment relies on observing players' movements and data from their sports equipment. Among the many pieces of original motion capture data are athletes' skeletal positions, as well as their acceleration, ground contact, and equipment trajectories. Here is the equation:

$$m = (x, c, t)^3 \tag{1}$$

It is from this first motion capture data that feature extraction is derived. Process p is computed to produce the immediate achievement (motion feature) after motion categorisation and examination are integrated with the item's characteristics. In general, there are three ways to classify the motion characteristics that have been gathered: the field of kin circumstances, and temporal synchronization. As a case study, badminton is used. The initial motion capture data consists of the three-dimensional shuttlecock and racquet direction. In contrast, the motion characteristics include the racquet's acceleration and the shuttlecock's flight duration before each match. This is how the equation is stated:

$$p = e(x, c, t) \tag{2}$$

Evaluating a sportsman involves scoring skill indicators based on their immediate performance. Due to the more abstract nature of skill indicators' definitions and computations, they are more difficult to use than sports characteristics. Merely the value $\hat{y}$ The associated skill measure may be determined from the immediate performance under a particular exercise content, as not all skill markers are closely connected to a given exercise content. The expression of the relationship equation on all three levels is:

$$\hat{y} = h(p) = h\big(e(m)\big) \tag{3}$$

A series of trials were conducted to monitor the motion of the upper limbs. One amateur badminton player will be the focus of the studies. The participant is instructed to do simple up-and-down motions with their upper limb. The goal of the human body action recognition module is to select a method that makes it easy to pinpoint certain locations on a person's body in a still picture or moving video. The real laws of motion must be conformed to by the location information of the important points collected for later follow-up. The action assessment was a success. After gathering actions, the next step is for the human body action recognition module to examine the video or picture and pull out the gesture information.

3.3. Action Evaluation

An established set of standards for describing activities is necessary to recognise human actions in visual media. To accomplish the action recognition effect, the data acquired from the human posture recognition module is processed according to the rules described in the action description. Figure 2 shows the rules flow for action descriptions in the action assessment process.

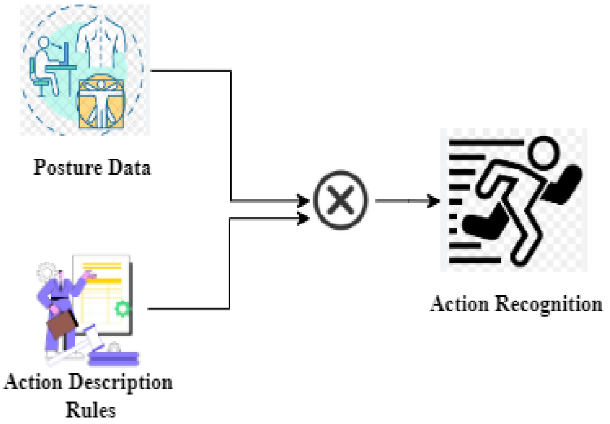

Figure 2. Action Evaluation

Joint Angle: The image-based approach of computing the cosine angle from three-point coordinates accurately determines the human body's joint angles as each joint point has a coordinate location. To characterise the motion, the joint angle is used. You can compare the two acts without knowing the length of the body's limbs, and then you can undertake the controlled confirmation. Pictured in Figure 3 are the human skeleton model and its associated skeletal labels. As seen in Figure 4, the three-point coordinate is reputedly founded on the principle of determining the joint angle between two vectors using the law of cosines.

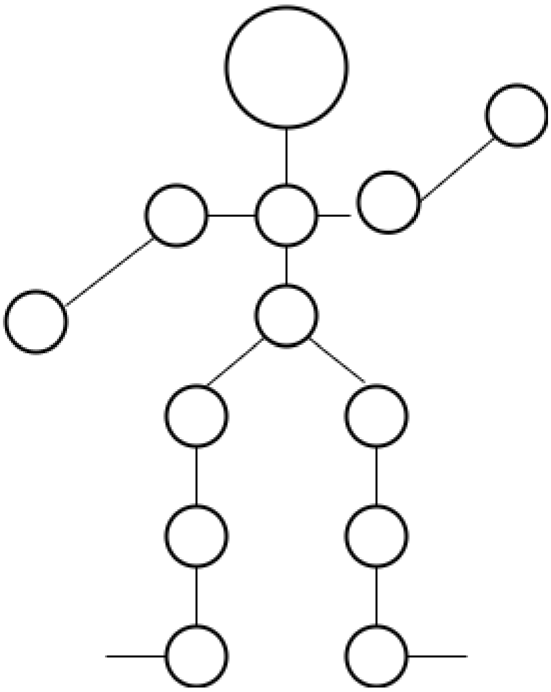

Figure 3. Skeleton model for motion capture

Here is the formula to determine the joint angle:

$$\overrightarrow{AB} = (x_2 - x_1, y_2 - y_1), \tag{4}$$

$$|AB| = ((x_2 - x_1)^2, (y_2 - y_1)^2)^{1/2} \tag{5}$$

$$\overrightarrow{BC} = (x_3 - x_2, y_3 - y_2), \tag{6}$$

$$|BC| = ((x_3 - x_2)^2, (y_3 - y_2)^2)^{1/2} \tag{7}$$

The cosine of the angle B at the joint may then be determined:

$$\cos B = \frac{\overrightarrow{AB} \times \overrightarrow{BC}}{|AB||AC|} \tag{8}$$

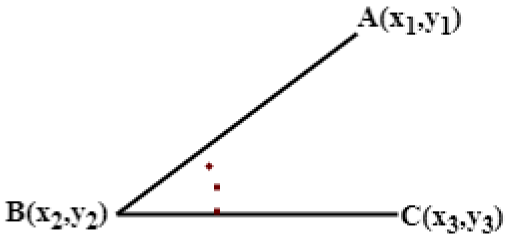

Figure 4. Angle of Skeleton Model

Action Similarity: To determine which athlete is doing the exercise more consistently, one must first determine the "distance" between the two executions of the movement. In this section, we present the idea of movement similarity. The idea of action similarity is fundamental to rules for describing activities, which has two applications: first, for recognising individual acts, and second, for determining which actions in a continuous series are most advantageous. Determine the separation between the two motions by comparing their joint angle data; this separation represents the degree of similarity between them. Two different types of multifunctional vectors were used to represent the joint angle data: $A_1, A_2, \ldots \ldots . A_n$ and $T_1, T_2, \ldots . \ldots\ T_n$ A stands for the action's joint angle that must be measured and T for the template action's joint angle. To find the distance between the two vectors, the formula for the Euclidean distance was utilised:

$$d(x, y) = (\sum_{i=1}^{n} (x_i - y_i)^2)^{1/2} \tag{9}$$

Then

$$distance = ((T_1 - A_1)^2 + (T_2 - A_2)^2 + (T_3 - A_3)^2 + \cdots + (T_n - A_n)^2)^{1/2} \tag{10}$$

Closer proximity indicates a more homogeneous activity.

3.4. Virtual Reality in Sports Training

This comprehensive research focuses on virtual reality's (VR) potential as a teaching and training tool in sports. VR is a high-level human-computer interface with three characteristics: immersion, interaction, and visualisation. Another name for VR is Lingjing technology. Users can completely lose themselves inside a virtual world thanks to advancements in computer graphics, emulators, interactive media, artificial intelligence, network connectivity, computing in parallel, and multi-parameter environmental sensing. In an immersive environment, users can move freely about and interact with objects and scenes just as they would in the real world, without ever having to use a mouse or keyboard. The characteristic that differentiates the VRT system from conventional three-dimensional cartoons is their level of interactivity. Instead of passively receiving data from computers, users may actively manipulate virtual objects to alter reality via interaction. By bringing together qualitative diagnosis and logical analysis, visualisation helps users gain perceptual and rational recognition, deepening their understanding and expanding their sense of perception. An input unit, display equipment, utility software system, professional picture disposal computer, and VRT system are the components of a VRT system. The primary components of the input apparatus are the data glove, tail-after-head system, solid earphones, and helmet indication. The software and virtual environment precisely specify the rules of interaction, organisation, and dynamic characteristics. The external equipment includes computer systems and picture-sound gear.

The growth and adoration of competitive sports have elevated the importance of game conditions to the level where they determine winners and losers. Many sports coaches are considering ways to simulate actual competition in training environments in an effort to enhance their athletes' skills. With VRT, the issue is resolved. Through its capabilities, it is possible to simulate a variety of training environments, including but not limited to calm, tight, and loud settings, as well as real-life competitions. Techniques, strategies, and endurance are all required by this training approach, disrupting conventional wisdom about training by creating an interactive relationship between athletes and virtual environments. With a lower injury rate in warm-up competition, training becomes more realistic while reducing investment.

3D Modeling: A 3D modelling system is a coordination-based method for creating three-dimensional representations of things. Mathematical operations are the backbone of this coordinating system's functioning. This setup is a part of a computer graphics application that models the surface of things in three dimensions. Using certain image manipulation techniques, the computer graphics application enables 3D modelling systems to transform 2D images into 3D models. 3D modelling systems have extensive use in several sports-related domains, particularly to enhance the field's operational mechanism. Figure 5 shows the VR Training analysis and 3D Modeling.

An item's 3D model may be generated using one of many 3D modelling technologies. Solid, wireframe, and surfaced 3D modelling systems are the three most prevalent kinds of 3D modelling systems out there. Software that can transform 2D images of objects into 3D models is the backbone of any 3D modelling system. Using 3D modelling technology is very important for both the sports field and players in the sports industry.

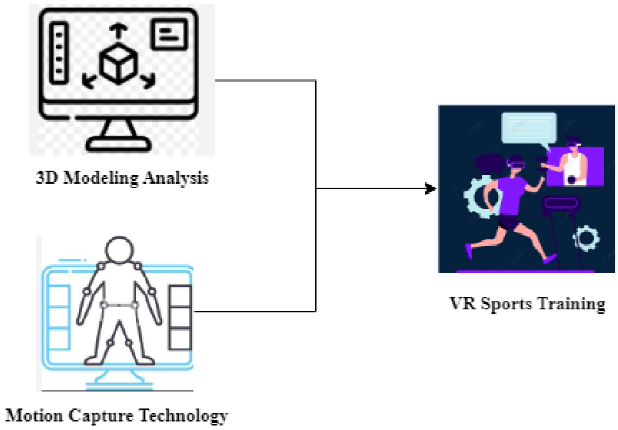

Figure 5. VR Sports Training Analysis

The 3D modelling technology is quite helpful in the area of sports education. Additionally, sports research investigations in the field may be completed much more quickly using 3D modelling technology. Athletes may better understand the playing field by interacting with the actual sports world in a virtual setting.

3.5. Augmented Reality in Sports Training

Several innovative measures and approaches for creating AR and VR experiences have been put forth in the last few years. There is a shortage of literature that uses immersive technologies in athletes' training, for instance, even though AR and VR have numerous established uses. Users' capacity to acquire and remember knowledge is improved when systems like AR repeatedly prove it via diverse channels. Augmented reality (AR) can potentially revolutionise many education delivery methods within this framework. It can provide new learning methods in areas where traditional methods have failed. Depending on whether the players are aiming to improve their behavioural, psychological, or biomechanical skills, training sessions may be classified into three main types.

The first group explains how the player may practice making good decisions to prepare for a certain situation, like a tournament. Psychological aspects that could influence a sportsperson's efficiency are addressed in the second group. The third category focuses on studying and refining movement mechanics to improve performance and prevent injuries. Considering both behavioural and biomechanical changes, this article suggests a multimodal approach to immersive training utilising AR. A real-time feedback system for certain motions (such as soccer, training, and sports) is also a part of it. The system will employ data from Inertial Measurement Units (IMUs), heart rate (HR), and interbeat interval (IBI) as part of the assessment.

IMU data

Accelerations in all three planes (x, y, z) may be detected using a tri-axial accelerometer. Using an IMU, one may get kinematic data, such as angles, between two joints.

$$v_{xyz} = [DCM]\begin{bmatrix} IMU_x \\ IMU_y \\ IMU_z \end{bmatrix} \quad (11)$$

$$\theta_{IMU} = atan\left(\frac{v_x}{v_z}\right) \quad (12)$$

$$\theta = \theta_{IMU1} - \theta_{IMU2} \quad (13)$$

This allows the accelerometers to identify weariness caused by variations in certain motions (such as the degree of angle in a particular joint). Further comparison with IMU readings will be done via tailored training using a machine-learning-based technique.

4. Experimental Results

Data about the technical moves made by badminton players during matches is used. Before the experiment, each video sequence is transformed into a grayscale picture, and the video is framed using the badminton basic action data set. This is how the video sequence is generated. This study uses a split of the badminton basic action data set into a training set and a test set to rapidly find the number of frames in the sampling interval by experimentally analysing just the top ten sports films from each set. In a comparison experiment, 40 frames were used as samples, with 8, 9, and 10 frames as sample intervals. This is used to determine athletes' average rate of accurate action recognition throughout 35 cycles of repeated training. After 20 training iterations, the model achieves a test accuracy of 95.38% with a sampling interval of 5. In most cases, the camera captures human movements at a rather modest rate. Using a greater sample frame interval might be helpful to gain more representative motion characteristics and minimise duplicate information.

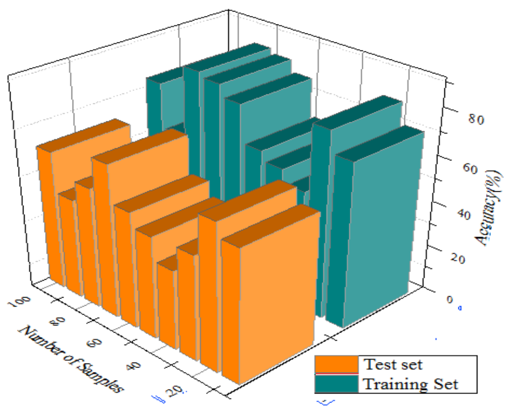

Figure 6. Accuracy of the proposed method

Five frames per second is the sample frame interval. The soft maximum probability approach is used to acquire the results of motion classification. This study proposes an optimisation approach that uses random gradients based on this data. Figure 6 shows the accuracy of the proposed method.

To better comprehend the algorithm's efficiency and behaviour, visualisation results play an essential part in several forms of emotion identification. To begin, it is possible to see how various emotion categories are distributed in the feature space and determine whether there are any noticeable clustering tendencies by visualising the findings. The ability of the model to distinguish various feelings, as well as any instances where these feelings overlap or get perplexed, may be ascertained in this way. The visualisation results may also show how well the model recognises various moods. If one looks at the hierarchy of confusion or the disparity between each of the classifications, they may see what kinds of feelings the model has an easier time recognizing and which ones could be harder. As a result, the model and its ability to accurately predict challenging emotions are enhanced.

Furthermore, the model's emotional recognition ability may be examined in various scenarios or across different periods using visualisation. Making a time series graph of emotional changes over time is one possibility; another is to study the model's emotional reaction in various settings. The stability and practicability of emotion recognition in various contexts may be better understood with this information. The error curves for the training set and the test set are shown in Figure 7.

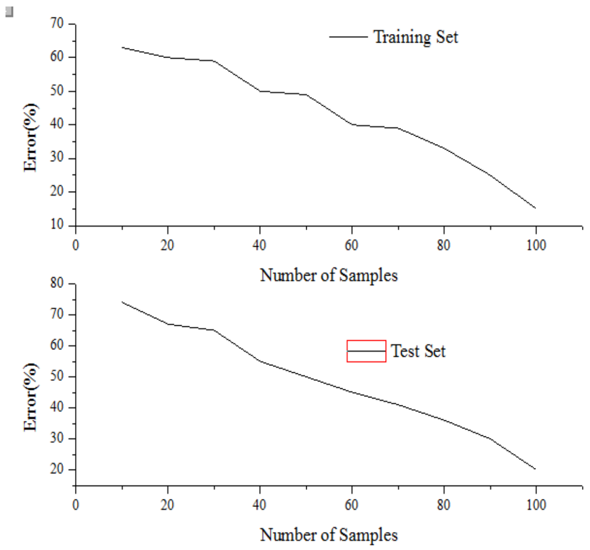

Figure 7. Error rate of training and test set

Findings from the Examination of Athletes' Motion Standardization

Athletes' bodies move in rhythm with each hitting round; in this context, assessing the motion standardisation means looking at the actions that go along with a certain striking round. Figure 8 shows the experimental findings for the ball's flight and the extension motion of the right arm of the athletes during the same round. In the trajectory diagram, the black curve represents the badminton's position changes along the table's long side, Indicated by the red curve are shifts in position along the vertical upward, and shifts are shown by the blue line. in position along the short side. A graph showing the change in the angle unit at the appropriate time for the shoulder joint extension angle is shown on the bottom side. As athletes move their arms forward, the extension angle increases in absolute terms.

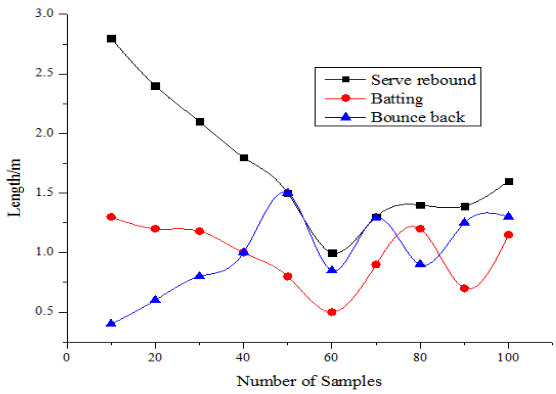

Figure.8. Badminton trajectory of receiving the ball

The maximum expansion pitch occurs just before contact. The experimental results show that each of the participants' degree dispersion in the framework is consistent with the actual scenario in terms of the returning ball's quality and normal range of movement. This demonstrates that the algorithm and approach may be beneficial given a limited number of samples, which sets the stage for more precise and comprehensive sports assessments and commentary in the years to come.

Evaluation of the Comparison Method vs. the Conventional Approach to Training

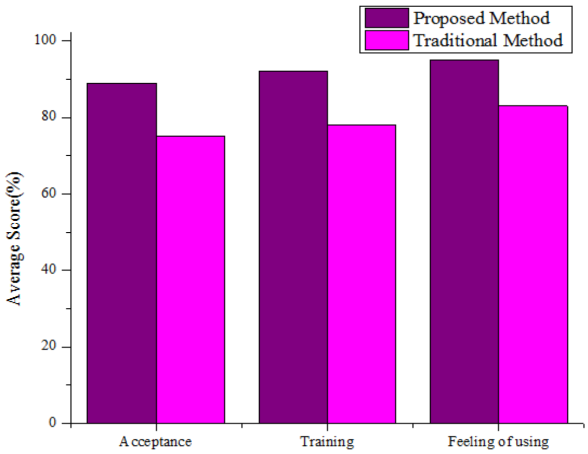

Figure 9. Comparative analysis of training effect of players

The suggested approach's application effect is being investigated using the Questionnaire Survey (QS) method. Thirty college athletes and six coaches have been selected as subjects. The QS uses the 5-point Likert rating system, where 1–5 scores represent unsatisfied and fully pleased, respectively. A higher score indicates a more favorable system effect. Three factors are considered while studying collegiate athletes: openness, motivation during training, and overall satisfaction. There are three angles from which coaches are examined: user experience, application difficulties, and acceptability. Figure 9 shows that the comparative analysis of the training effect of players.
The results of the comparative study of the training effects of coaches are shown in Figure 10.

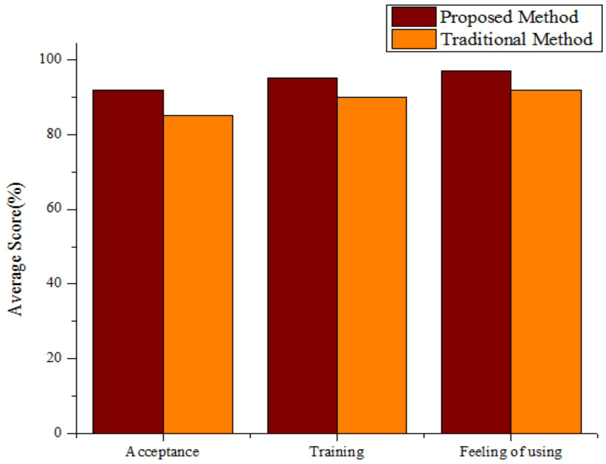

Figure 10. Comparative analysis of training effect of coaches

Here, experimental evidence supports the claimed badminton training system's efficacy. The suggested approach may precisely mark the starting data to achieve high system performance in serve modes. The second advantage is that the technology can precisely determine the serve's trajectory. Missed receptions, balls that fall off the table, and balls that contact the net are the three main categories into which issues with the ball-receiving step fall. According to QS findings, the suggested approach has an excellent overall application impact. Full improvement of college athletes' training passion is achieved by the suggested intelligent training approach, which outperforms the old way regarding user experience and acceptability. It is recommended that the suggested method's use stages be further streamlined and its application scope be broadened in the follow-up research.

5. Conclusion

This research presents a model for an athlete's training and action recognition that combines AI and CV using two virtual and augmented reality channels. After that, the coaching system detects trajectories and trains badminton. The approach to building athletes' skill-level models is conceived from the standpoint of interactive training. Badminton and racket trajectories are captured using an optical motion capture system, while human posture is restored using an inertial motion capture system. To further enhance the accuracy of human inertial motion capture, experimental findings show that correcting the human body's posture is very smooth when subjected to contact position limitation. In addition, the real-life scenario aligns with the uniform distribution of the returning ball's quality and the standard of motion. Initial testing focuses on ensuring the platform is easy to use and that the sports assessment approach is effective. Based on real data, the suggested strategy outperforms the conventional training method regarding application effect. This article proposes a few deep learning approaches for action recognition, excellent results in classifying have been obtained.

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