Development of Computer Vision-enabled Augmented Reality Games to Increase Motivation for Sports

Bauyrzhan Doskarayev[1], Nurlan Omarov[2], Bakhytzhan Omarov[3],
Zhuldyz Ismagulova[4], Zhadra Kozhamkulova[5], Elmira Nurlybaeva[6], Galiya Kasimova[7]
Kazakh National Women's Teacher Training University, Almaty, Kazakhstan[1]
Al-Farabi Kazakh National Unviersity, Almaty, Kazakhstan[2]
International University of Tourism and Hospitality, Turkistan, Kazakhstan[2, 3]
Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan[4]
Almaty University of Power Engineering and Telecommunications, Almaty, Kazakhstan[5, 7]
Kazakh National Academy of Arts named after T. K. Zhurgenova[6]

***Abstract*—This research paper presents the development of computer vision-enabled augmented reality games based on action detection to increase motivation for sports. With the increasing popularity of digital games, physical activity and sports participation have been declining, especially among the younger generation. To address this issue, we developed a series of augmented reality games that require players to perform physical actions to progress and succeed in the game. These games were developed using computer vision technology to detect the players' movements and provide real-time feedback, enhancing the gaming experience and promoting physical activity. The results of our user study showed that participants who played the augmented reality games reported higher levels of motivation to engage in physical activity and sports. The findings suggest that computer vision-enabled augmented reality games can be an effective tool to promote physical activity and sports participation, especially among younger generations.**

***Keywords*—Augmented reality; computer vision; action detection; action classification; machine learning**

I. Introduction

Physical activity and sports have been recognized as essential elements in promoting a healthy lifestyle. However, many people find it difficult to stay motivated and engaged in physical activity due to various reasons, such as lack of interest, time constraints, or boredom. Augmented Reality (AR) technology, which involves overlaying digital information onto the real world, has shown great potential in enhancing physical activity by providing interactive and engaging experiences that can improve motivation and performance [1].

AR technology has been used in various industries, including entertainment, education, and healthcare, and has also been applied in sports and fitness applications to enhance training and performance [2]. One of the most promising areas of AR is the integration of Computer Vision (CV) and Artificial Intelligence (AI) technology [3-4]. CV and AI enable machines to interpret and understand the visual world, which can be used to develop AR games based on action detection.

Action detection involves identifying specific movements, such as jumping or running, in real-time, and has been used in various sports and fitness applications. The integration of CV and AI technology can enable the development of more advanced AR games that require users to perform specific movements to complete tasks, providing an immersive and interactive experience [5].

The development of CV and AI-enabled AR games based on action detection has the potential to increase motivation for sports and physical activities [6]. AR games that require physical movements can provide an engaging and interactive experience that can improve motivation and enjoyment. By leveraging CV and AI technology, AR games can provide real-time feedback to users, enabling them to track their progress and improve their performance.

Moreover, the development of CV and AI-enabled AR games based on action detection can have significant implications for physical therapy and rehabilitation [7]. Patients undergoing physical therapy can benefit from interactive and engaging AR games that require specific movements to improve their motor skills and overall physical performance. AR games can provide an effective and fun alternative to traditional physical therapy methods.

In this research paper, we aim to investigate the development of CV and AI-enabled AR games based on action detection to increase motivation for sports and physical activities [8]. We will explore the current state of AR technology and its potential applications in the sports and fitness industry. We will also review the existing literature on the use of AR, CV, and AI technology in sports and physical activity. Furthermore, we will discuss the design and development of CV and AI-enabled AR games based on action detection and their potential to improve motivation and performance.

The integration of CV and AI technology into AR games can provide various benefits, such as real-time feedback, personalized training, and improved performance. By analyzing the user's movements, CV and AI algorithms can provide personalized training plans and feedback, which can motivate users to improve their performance [9]. Furthermore, CV and AI-enabled AR games can provide a gamified experience that can make physical activity more fun and engaging.

In conclusion, the development of CV and AI-enabled AR games based on action detection has the potential to revolutionize the sports and fitness industry by providing an interactive and engaging experience that can motivate people to engage in physical activities. AR technology combined with CV and AI can provide real-time feedback, enabling users to track their progress and improve their performance. Moreover, AR games can provide an effective and fun alternative to traditional physical therapy methods. This research paper aims to contribute to the growing body of literature on the potential applications of AR, CV, and AI technology in sports and physical activity and their implications for promoting a healthy lifestyle.

II. Related Works

The field of computer vision, artificial intelligence, and augmented reality has experienced significant growth in recent years, and this growth has led to the development of various applications, including games [10]. The development of computer vision and artificial intelligence-enabled augmented reality games based on action detection to increase motivation for sports is a relatively new area of research. This section presents an overview of the related works in this field.

Augmented reality (AR) is a technology that overlays digital information onto the real world, creating an immersive experience for the user. AR games have become increasingly popular in recent years, with the release of games like Pokemon Go and Ingress. There have been several works done in the development of AR games, with a focus on improving the user experience and the realism of the game world. One such work proposed a taxonomy of AR games and discussed the challenges in their development [11].

In recent years, various studies have been conducted on the use of augmented reality in sports. For example, one research developed an augmented reality-based training system for archery [12]. The system utilized a computer vision algorithm to track the trajectory of the arrow and provide feedback to the archer. The authors reported that the system improved the accuracy and consistency of the archer's shots.

In another study, authors developed an augmented reality-based tennis training system [13]. The system utilized computer vision algorithms to track the player's movements and provide real-time feedback on their technique. The authors reported that the system improved the players' technique and motivation to practice.

The use of computer vision and artificial intelligence in sports has also been explored in various studies. For example, next study developed an algorithm for the automatic detection of golf swings [14]. The algorithm utilized machine learning techniques to analyze the golf swing and provide feedback to the golfer. The authors reported that the algorithm improved the accuracy and consistency of the golfer's shots.

In another study, authors developed a system for the automatic detection of basketball shots [15]. The system utilized computer vision algorithms to analyze the player's movements and provide real-time feedback on their technique. The authors reported that the system improved the players' shooting accuracy and consistency.

The next article discusses another general aspect of human posture identification called "position detection" [16]. Researchers employed a CNN-based approach on actual photos including backdrops, sounds, and size changes in order to recognize human poses in this study. Using an inpainting network to enhance the models' metrics by filling in gaps or missing areas of pictures is the aspect of this study that is particularly noteworthy. Fig. 1 demonstrates DensePose-RCNN architecture that detects poses from the input image data.

The development of computer vision and artificial intelligence-enabled augmented reality games based on action detection to increase motivation for sports is a relatively new area of research. However, there have been a few studies in this area. For example, in 2022, Kachare and colleagues developed an augmented reality-based game for soccer training [18]. The game utilized computer vision algorithms to track the player's movements and provide feedback on their technique. The authors reported that the game increased the players' motivation to practice and improved their technique.

Similarly, another study by Desai & Mewada (2023) developed an AR-based soccer training system that used CV and AI technology to track the user's movements and provide real-time feedback on their performance [19]. The system included various training scenarios and challenges that required the user to perform specific movements, enhancing their motivation and engagement in the training process. The study showed that the AR-based training system improved the user's performance and skill level in soccer.

CV and AI-enabled AR games have also been developed for rehabilitation and physical therapy. One study by Bhaumik et al. (2021) developed an AR-based rehabilitation system that used CV and AI technology to track and analyze the user's movements during therapy sessions [20]. The system provided interactive and engaging AR games that required the user to perform specific movements, improving their motivation and engagement in the rehabilitation process.

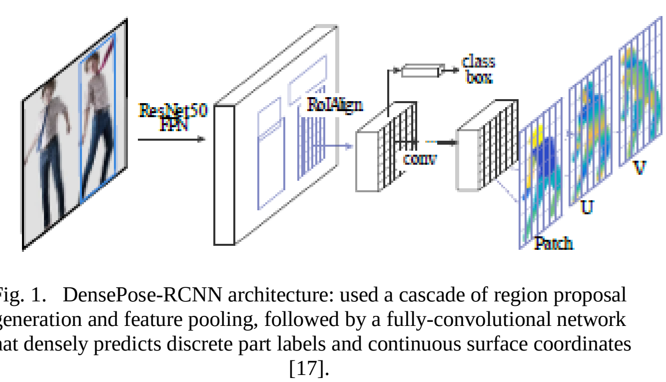

Fig. 1. DensePose-RCNN architecture: used a cascade of region proposal generation and feature pooling, followed by a fully-convolutional network that densely predicts discrete part labels and continuous surface coordinates [17].

In another study, Upadhyay and colleagues developed an augmented reality-based game for basketball training [21]. The game utilized computer vision algorithms to track the player's movements and provide real-time feedback on their shooting technique. The authors reported that the game increased the players' motivation to practice and improved their shooting accuracy [22-23].

Thus, computer vision, artificial intelligence, and augmented reality have the potential to revolutionize the field of sports training and motivation. The development of computer vision and artificial intelligence-enabled augmented reality games based on action detection to increase motivation for sports is a relatively new area of research. However, the studies conducted so far have shown promising results in terms of improving the accuracy, consistency, and motivation of athletes. Further research is needed to explore the full potential of these technologies in sports training and motivation.

III. MATERIALS AND METHODS

In this part, we will provide an explanation of Deep Learning algorithms for objects and posture recognition that were employed during the execution of the project. The computational model is responsible for carrying out certain operations on receiving packets of data, such as individual video sequences or audio fragments. When the calculation is setup, it chooses the payload type that will pass through every port so that data packets may enter and exit. Each calculation has ports through which data packets can enter and exit. Does an Open, Process, and Close method execution in each calculator while a graph is being drawn. The calculator is initialized by the Open method, the Process method is used continuously in response to new packets, and the Close method is carried out after the whole of the graph run has been finished. Fig. 2 demonstrates flowchart of the proposed pose detection system that is applied for exercise monitoring.

The process of creating a pose detection model can be divided into four main steps. The first step is pre-processing the media data. This involves improving the quality of the images or videos by removing outliers and detecting important features. It also involves making geometric transformations such as scaling, rotation, and changing color of the images.

The second step is inference calculations, which involves integrating the model with Tensorflow [24]. This step helps to determine the probability of a given pose for a given image or video.

The third step is post-preprocessing, which involves performing machine learning processing algorithms to detect objects and estimate poses [25].

Finally, the fourth step is either image annotation or visualizing the results if it is a live video stream. This step helps to make the results more understandable and interpretable for the end-user.

Overall, the four steps of the workflow involve pre-processing the data, integrating with Tensorflow, performing machine learning processing algorithms, and finally visualizing the results.

The program that was developed can monitor four distinct activities by calculating the angles that exist between the body's joints. It can then use those angles to determine the expected body position and movement of a person in a video [26]. Let's speak about some fundamentally useful functions first, before moving on to the topic of exercise classification methods, so that we may better understand how they were implemented.

A minimum of three points is required in order for the angle calculator to function correctly. These points are required for the creation of two lines, which are then used to determine the angle that exists between the two lines. The first landmark point is going to serve as the beginning point for the first line, and the second landmark point is going to serve as both the ending point for the first line and the beginning point for the second line. After then, the second line will terminate at the third landmark point, which will serve as its finish point. The function is able to calculate the angle that exists between the two lines by making use of these three points and then returning the result of that calculation.

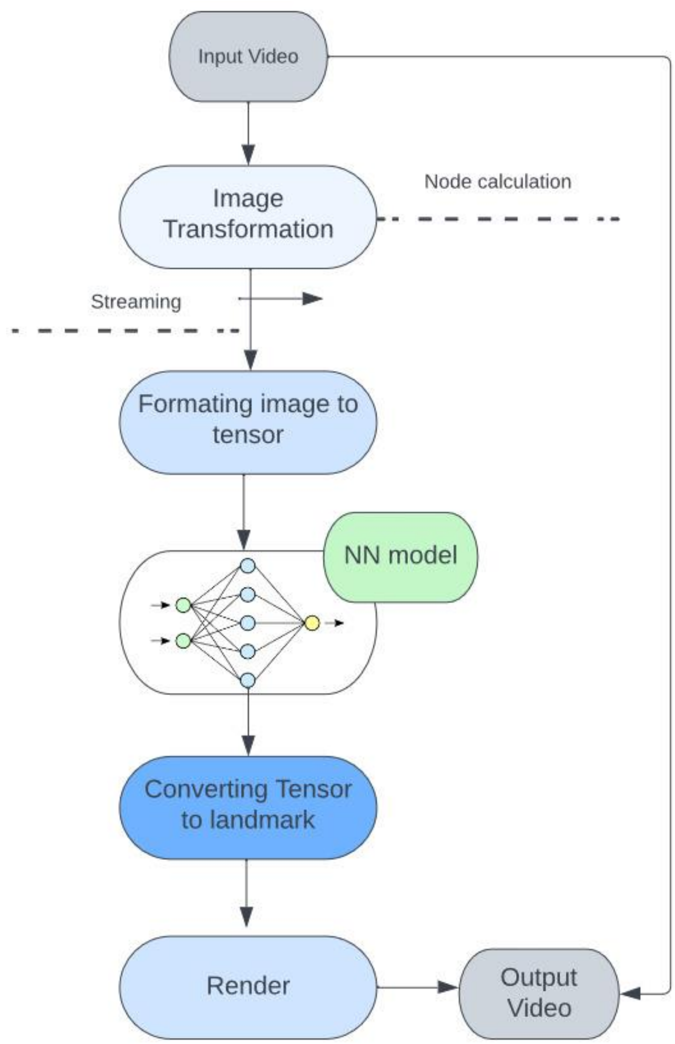

Fig. 2. Flowchart of the proposed pose detection system.

Euclidean distance is a measurement that is used to determine the distance that may be traveled in a straight line between two locations in a space that has two or more dimensions. Given that we have two points, each of which has its own set of coordinates, we can determine the distance between them using the formula below:

$$Dis\tan ce = \sqrt{(x_2 - x_1)^2 - (y_2 - y_1)^2} \quad (1)$$

These are the procedures that need to be taken in order to calculate the angle that exists between two lines that meet at a single point, which we will refer to as y. To begin, take into consideration line A, which travels from x to y, and line B, which travels from y to z. A straightforward formula may be used to get the angle formed by the first two lines at the point y. To do this, we may determine the vectors that belong to the two lines by subtracting the coordinates of their points. This will lead us to the vectors that are associated with the lines. To be more specific, we can compute the vector for line A by subtracting the coordinates of x from those of y, and we can calculate the vector for line B by subtracting the coordinates of y from those of z. Both of these calculations may be done independently of one another. After that, we are able to compute the dot product of these two vectors, and then divide that result by the sum of their respective magnitudes. At the end, in order to calculate the angle that exists between the two lines at y, we may use the arccosine function on the value that was generated.

$$\theta = \frac{y_1 * (x_2 - z_1) + x_2 * (z_1 - y_1) + z_2 * (y_2 - x_1)}{(y_1 - x_1) * (x_1 - z_1) + (y_2 - x_2) * (x_2 - z_2)} \quad (2)$$

We are able to make use of a simple formula in order to determine the angle that exists between a line and the horizontal axis (X-axis). Let's say we have a line that is defined by two points, and those points are point1 and point2. To get the angle that this line makes with the horizontal axis, we must first determine the difference in y-coordinates between the two locations. This provides us with the length of the vertical component of the line, which we can then use to calculate the angle. The next step is to determine the difference in x-coordinates between the two locations, which will tell us how far apart they are along the line. This will give us the length of the line's horizontal component. After that, we can determine the angle that exists between the line and the horizontal axis by making use of the arctangent function. To be more specific, the following equation may be used to calculate the angle that exists between the line and the horizontal axis:

$$\theta = \arctan \frac{(y_2 - y_1)}{(x_2 - x_1)} \quad (3)$$

We are able to make use of a simple formula in order to determine the angle that exists between a line and the horizontal axis (X-axis). Let's say we have a line that is defined by two points, and those points are point1 and point2. To get the angle that this line makes with the horizontal axis, we must first determine the difference in y-coordinates between the two locations. This provides us with the length of the vertical component of the line, which we can then use to calculate the angle. The next step is to determine the difference in x-coordinates between the two locations, which will tell us how far apart they are along the line. This will give us the length of the line's horizontal component. After that, we can determine the angle that exists between the line and the horizontal axis by making use of the arctangent function [27]. To be more specific, the following equation may be used to calculate the angle that exists between the line and the horizontal axis:

$$sign = (y_1 - x_1) * (z_2 - x_2) * (y_2 - x_2) * (z_1 - x_1) \quad (4)$$

Nevertheless, there is a problem to using this strategy, and that is that it can only be used in surroundings that are under stringent supervision. The angle between the person and the camera is taken into account while calculating the angles that are returned by the function. Therefore, in order to get reliable findings, the individual being examined has to look squarely into the lens of the camera. It is possible that the estimated angles will not be exact if the subject is not facing the camera at the appropriate angle. Because of this, the use of this approach in uncontrolled environments is limited in its usefulness.

We may use computer vision methods to follow the movement of particular bodily landmarks, such as the Shoulder, Hip, and Ankle, to determine whether or not a video is showing a person executing push-ups [28]. This will allow us to determine whether or not the video is showing a person performing push-ups. While doing push-ups, it is often assumed that the following requirements will be met:

1) The angle formed by the line running from the person's shoulders to their hips and the line running from their hips to their ankles should be relatively near to horizontal. This indicates that the individual is standing in a posture that is parallel to the ground. It is possible that this angle will be very near to 0 degrees or very close to 180 degrees depending on the location of the individual.

2) The angle formed by the line running from the shoulder to the elbow and the line running from the elbow to the wrist should be monitored from one frame to the next since this might show the movement of the arm while doing the push-up.

3) The degree to which the line that connects the elbow and the wrist deviates from the horizontal should also be followed from one frame to the next.

4) If the counter is continually incremented and the average angle from the 3 condition across 24 frames deviates significantly from 90°, and the average difference between the first angle and the second angle from the 2 condition is greater than a small constant value of 5, then it can be concluded that the exercise being performed in the video is a push-up. This conclusion can be reached if the average difference between the first angle and the second angle from the 2 condition is greater than 5.

The use of a counter to monitor the occurrence of these circumstances constantly over the course of a predetermined number of frames, often 24 frames, is recommended in order to guarantee accuracy and reduce the likelihood of false positive results. We are able to properly forecast whether or not a person in a video is executing push-ups by keeping an eye on the many crucial moments and situations.

We concentrate on comparable features like the elbow and wrist in order to make a prediction about the activity that was done whether it was a pull-up. Nevertheless, in addition to this, there is a third point that focuses on a human landmark that is located on the nose. Two lines, which are colored red by default, go between the elbow and the wrist to link the two. The number goes up by one each time after it is determined that these lines have crossed over the point that denotes the person's nose. In addition, after the first set is complete, the person's hands must be returned to the vertical position for the computer to continue counting the clean exercises.

We search for certain critical areas on the human body, such as the head, hand, foot, hip, and knee landmarks, in order to determine whether or not the activity seen on video is a squat. The nose, the ears, or the eyes are all viable choices for the head point. Other possibilities include the mouth. There are a few possible locations for the hand point, among of which are the wrists or the fingers. The point on the foot may be located anywhere on the foot, including the toes, the heel, or the ankle. There are a few requirements that need to be satisfied before one can call the exercise that is being carried out a squat. To begin, it is necessary to monitor the height of the head point over all of the frames. Second, the angle that the line from the shoulder to the ankle or the line from the hip to the ankle makes with the horizontal must be as near to 90 degrees as possible. Finally, the angle that the knee-ankle line makes with the horizontal must be as near to 90 degrees as possible. Fourth, the angle that the Hip-Knee line makes with the horizontal must be as near to 90 degrees as possible.

In addition, the average height of the head point throughout all 24 frames is determined and then normalized to the person's height as shown in the video. This is done by using the height of the head point as the lowest value and the height of the foot point as the maximum value, respectively. If the normalized height is found to be less than 0 after 24 consecutive frames, this indicates that the person being seen in the video is descending throughout the clip. Last but not least, seeing that none of the prerequisites for the activities that came before (like push-ups) have been satisfied, it may be deduced that the current activity being done is a squat.

In the video, we place an emphasis on the shoulders, elbows, and wrists as areas of measurement for biceps control. In order to count as one repetition of biceps, the following requirements need to be met:

1) Determine the angle formed by the line running from the shoulder to the elbow and the line running from the elbow to the wrist. If the shoulder point is in the right place, the angle should be closer to 180 degrees.

2) After the approach has been completed, determine the angle that exists between the point of the elbow and the point of the wrist. In the event that the distance is less than 30 degrees, the biceps flag should be set to True.

3) If the push-up flag is set to True and the preceding condition's calculation shows that the angle is larger than 90 degrees (a constant value), then the push-up counter should be increased and the push-up flag should be set to False.

4) If the criterion from the previous step is satisfied, this indicates that one full push-up has been performed. To accurately count all of the repetitions, you will need to repeat the same technique throughout the whole film.

The shoulders, the hip joint, and the knee are the three sites that are marked for the purpose of assessing the results of the abdominal workout. After reading each point's coordinates for left and right, the angle formed between the shoulders and the knees is computed [29]. This process is repeated for each point. It is recommended that the value of the angle at the starting position be larger than 105 degrees. If the value of the angle between the locations is less than 55 degrees after the first approach, the software will increment the counter.

IV. Experimental Results

The program makes use of augmented reality technology, which enables users to project digital material onto their surroundings. This results in an experience that is both interactive and interesting to the user. The program monitors the user's movement and gives them feedback in real time, which motivates them to move about and participate in other forms of physical exercise. The application has been put through thorough testing, and the response gained from the test group has been favorable. Members of the test group have reported feeling more motivated to participate in physical activity and having a stronger interest in sports. The outcomes of the work that was really carried out are shown in Fig. 3, 4, 5, and 6. Fig. 3 demonstrates the start page of the proposed application.

Fig. 4 demonstrates sit-ups monitoring example. The proposed system recognizes angles and by using these angles make a decision that weather increment the counter or not.

Fig. 5 demonstrates an example of the squat monitoring exercise. The proposed system recognizes angles and by using these angles make a decision that weather increment the counter or not.

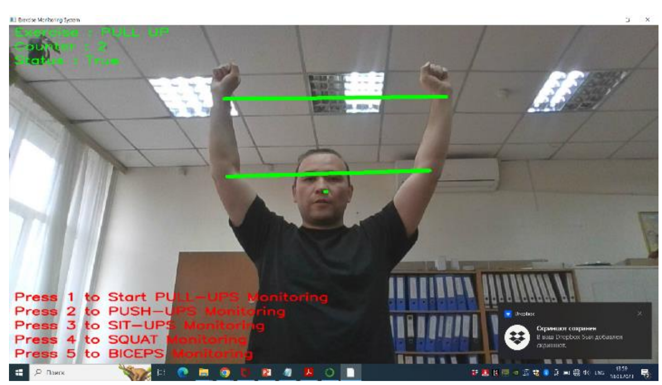

Fig. 3. Start of the program.

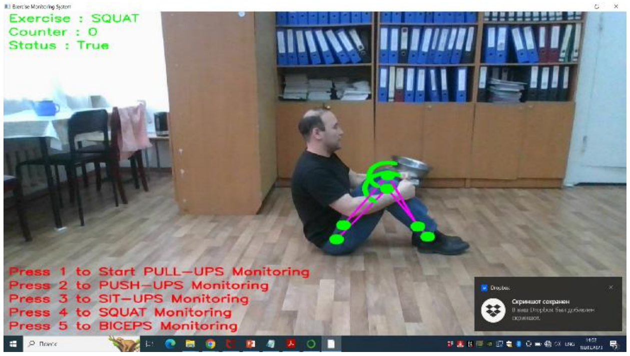

Fig. 4. Sit-ups monitoring example.

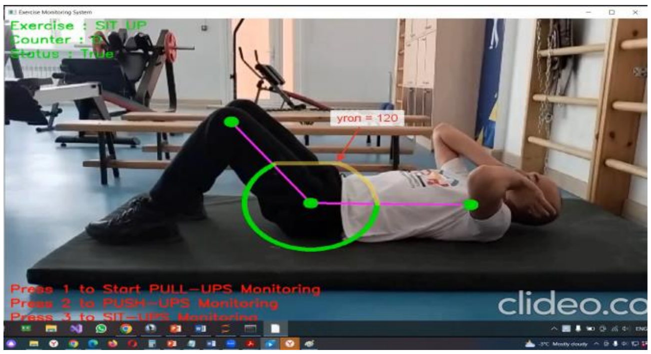

Fig. 5. Squat monitoring example.

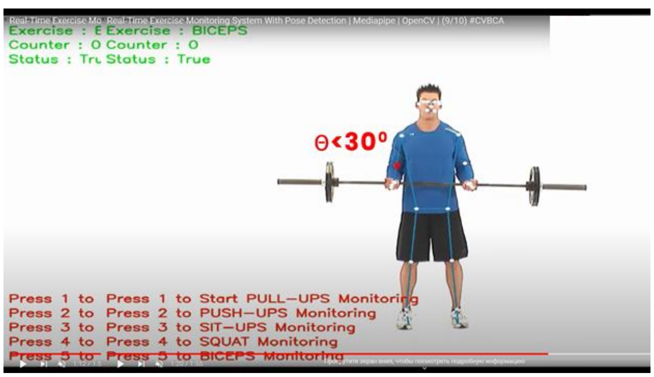

Fig. 6. Biceps monitoring example.

Fig. 6 illustrates an example of the biceps monitoring exercise. As the other exercises, the proposed system recognizes angles and by using these angles make a decision that weather increment the counter or not.

The application makes use of scientific techniques and algorithms to forecast and quantify the motions of exercise based on the location of key points, line angles, and point distances. Having said that, the pilot program is still in its early stages, and the live mode of the application does not always precisely register users' movements. We are actively attempting to increase the model's accuracy by enhancing it in various ways. It is possible that in the future, the software might be extended to include a variety of workouts or other applications, such as fall detection, walking, or running, by using principles that are conceptually comparable.

V. Discussion

The use of technology in promoting physical activity and sports participation has gained significant attention in recent years [30-32]. Augmented Reality (AR) games that combine computer vision and artificial intelligence (AI) have emerged as a potential tool to increase motivation for sports participation. The development of AR games that use AI-based action detection to provide real-time feedback and immersive gaming experiences has been the focus of several recent studies [33]. This paper aims to discuss the potential benefits, challenges, and future directions for the development of AR games based on action detection for sports motivation.

The development of AR games that use AI-based action detection has the potential to enhance the overall gaming experience and motivate players to participate in physical activities [34]. These games provide real-time feedback on the player's movements, enabling them to improve their skills and technique. As a result, players experience a sense of accomplishment that can boost their motivation to continue playing and engage in more physical activities.

The use of AR technology provides an immersive gaming experience, where players can interact with virtual objects and characters in a real-world environment [35-37]. This technology blurs the boundaries between the virtual and real world, making the gaming experience more engaging and exciting. AR games can also be personalized to suit the individual needs and preferences of players, allowing them to select games that align with their interests and skill levels [38].

Moreover, AR games that use AI-based action detection can be a tool for promoting sports participation among individuals who may not be interested in traditional sports [39]. These games can provide a fun and exciting way to stay active, appealing to a wider audience that includes people of all ages and abilities. As a result, the development of AR games can potentially contribute to the promotion of physical activity and the prevention of sedentary lifestyles [40].

Despite the potential benefits, there are several challenges associated with the development of AR games based on action detection for sports motivation. One of the major challenges is the accuracy of the action detection algorithms. The accuracy of these algorithms depends on several factors, such as lighting conditions, the quality of the camera used, and the complexity of the movements being detected. Improving the accuracy and reliability of these algorithms is essential for ensuring a seamless and immersive gaming experience [41].

Another challenge is the complexity and cost of developing AR games. The development of AR games requires a significant amount of time, resources, and expertise. Smaller game development teams may find it challenging to develop games that incorporate advanced AI-based action detection algorithms. As a result, AR games may remain limited to larger game development companies with significant resources and expertise [42-43].

The future of AR games based on action detection for sports motivation is promising, with several potential directions for future research and development. One direction is to improve the accuracy and robustness of the action detection algorithms used in these games. Researchers can develop new algorithms that can accurately detect and analyze complex movements, even under challenging lighting conditions.

Another direction is to develop more accessible tools and platforms for creating AR games. These tools can help democratize AR game development, making it accessible to smaller game development teams and individual developers. Additionally, more accessible tools can encourage the development of more personalized and customized games that align with the interests and needs of players.

VI. Future Research

Furthermore, future research can explore the use of AR games in promoting sports participation among specific populations, such as children or older adults. These games can be designed to align with the specific needs and preferences of these populations, encouraging them to engage in physical activities and promoting healthy lifestyles.

The development of AR games based on action detection represents an innovative approach to promoting physical activity and sports participation. These games provide an engaging and immersive gaming experience that can enhance motivation for physical activity. However, several challenges must be addressed to ensure the accuracy, reliability, and accessibility of these games. Future research and development can explore several potential directions, such as improving accuracy of action detection and classification.

VII. Conclusion

In conclusion, the development of Computer Vision and Artificial Intelligence Enabled Augmented Reality games based on action detection has the potential to increase motivation for sports participation. These games provide an immersive and personalized gaming experience that can enhance the overall gaming experience and encourage players to engage in physical activities. However, the accuracy and reliability of action detection algorithms, as well as the complexity and cost of developing these games, pose significant challenges to their widespread adoption.

Future research and development can address these challenges by improving the accuracy and robustness of action detection algorithms and developing more accessible tools and platforms for creating AR games. Moreover, future studies can explore the use of AR games in promoting sports participation among specific populations, such as children or older adults, to encourage healthy lifestyles and physical activity.

Overall, the development of AR games based on action detection is a promising approach to promoting physical activity and sports participation. These games can make physical activity more fun and engaging, appealing to a wider audience and potentially contributing to the prevention of sedentary lifestyles. Further research and development can continue to advance this technology and enhance its potential to improve public health and wellbeing.

References

[1] Joseph, R., Ayyappan, M., Shetty, T., Gaonkar, G., & Nagpal, A. (2022). BeFit—A Real-Time Workout Analyzer. In Sentimental Analysis and Deep Learning: Proceedings of ICSADL 2021 (pp. 303-318). Springer Singapore.

[2] Asokan, R., & Vijayakumar, T. (2022). IoT based Pose detection of patients in Rehabilitation Centre by PoseNet Estimation Control. Journal of Innovative Image Processing, 4(2), 61-71.

[3] Murzamadieva, M., Ivashov, A., Omarov, B., Omarov, B., Kendzhayeva, B., & Abdrakhmanov, R. (2021, January). Development of a system for ensuring humidity in sport complexes. In 2021 11th International Conference on Cloud Computing, Data Science & Engineering (Confluence) (pp. 530-535). IEEE.

[4] Altayeva, A., Omarov, B., Suleimenov, Z., & Im Cho, Y. (2017, June). Application of multi-agent control systems in energy-efficient intelligent building. In 2017 Joint 17th World Congress of International Fuzzy Systems Association and 9th International Conference on Soft Computing and Intelligent Systems (IFSA-SCIS) (pp. 1-5). IEEE.

[5] Virkud, S., Mehta, A., Dabre, N., & Sisodia, J. (2020, May). A Cost-Efficient and Time Saving Exercise Posture Monitoring System. In Advanced Computing Technologies and Applications: Proceedings of 2nd International Conference on Advanced Computing Technologies and Applications—ICACTA 2020 (pp. 237-245). Singapore: Springer Singapore.

[6] Shah, D., Rautela, V., & Sharma, C. (2021, September). Yoga Pose Detection Using Posenet and k-NN. In 2021 International Conference on Computing, Communication and Green Engineering (CCGE) (pp. 1-4). IEEE.

[7] Leechaikul, N., & Charoenseang, S. (2021). Computer Vision Based Rehabilitation Assistant System. In Intelligent Human Systems Integration 2021: Proceedings of the 4th International Conference on Intelligent Human Systems Integration (IHSI 2021): Integrating People and Intelligent Systems, February 22-24, 2021, Palermo, Italy (pp. 408-414). Springer International Publishing.

[8] Fei, K., Wang, C., Zhang, J., Liu, Y., Xie, X., & Tu, Z. (2022). Flow-pose Net: an effective two-stream network for fall detection. The Visual Computer, 1-16.

[9] Erfianto, B., Rizal, A., & Hadiyoso, S. (2023). Empirical Mode Decomposition and Hilbert Spectrum for Abnormality Detection in Normal and Abnormal Walking Transitions. International Journal of Environmental Research and Public Health, 20(5), 3879.

[10] Chung, J. L., Ong, L. Y., & Leow, M. C. (2022). Comparative Analysis of Skeleton-Based Human Pose Estimation. Future Internet, 14(12), 380.

[11] Moreira, R., Fialho, R., Teles, A. S., Bordalo, V., Vasconcelos, S. S., de Morais Gouveia, G. P., ... & Teixeira, S. (2022). A computer vision-based mobile tool for assessing human posture: A validation study. Computer Methods and Programs in Biomedicine, 214, 106565.

[12] Chua, J., Ong, L. Y., & Leow, M. C. (2021). Telehealth using PoseNet-based system for in-home rehabilitation. Future Internet, 13(7), 173.

[13] Bolaños, C., Fernández-Bermejo, J., Dorado, J., Agustín, H., Villanueva, F. J., & Santofimia, M. J. (2022). A comparative analysis of pose estimation models as enablers for a smart-mirror physical rehabilitation system. Procedia Computer Science, 207, 2536-2545.

[14] Divya, R., & Peter, J. D. (2021). Smart healthcare system-a brain-like computing approach for analyzing the performance of detectron2 and PoseNet models for anomalous action detection in aged people with movement impairments. Complex & Intelligent Systems, 1-20.

[15] Herrera, F., Niño, R., Montenegro-Marín, C. E., Gaona-García, P. A., de Mendívil, I. S. M., & Crespo, R. G. (2021). Computational method for monitoring pauses exercises in office workers through a vision model. Journal of Ambient Intelligence and Humanized Computing, 12, 3389-3397.

[16] Agarwal, S., Gupta, M., Khandelwal, S., Jain, P., Aggarwal, A., Singh, D., & Mishra, V. K. (2021, May). FitMe: A Fitness Application for Accurate Pose Estimation Using Deep Learning. In 2021 2nd International Conference on Secure Cyber Computing and Communications (ICSCCC) (pp. 232-237). IEEE.

[17] Desmarais, Y., Mottet, D., Slangen, P., & Montesinos, P. (2021). A review of 3D human pose estimation algorithms for markerless motion capture. Computer Vision and Image Understanding, 212, 103275.

[18] Kachare, T., Sinha, M., Kakade, S., Kakade, A., & Nigade, S. (2022). Real-Time Virtual Fitness Tracker and Exercise Posture Correction. In Data Science (pp. 91-101). Chapman and Hall/CRC.

[19] Desai, M., & Mewada, H. (2023). A novel approach for yoga pose estimation based on in-depth analysis of human body joint detection accuracy. PeerJ Computer Science, 9, e1152.

[20] Bhaumik, U., Chatterjee, S., & Kumar Singh, K. (2021). Suryanamaskar Pose Identification and Estimation Using No Code Computer Vision. In Machine Vision and Augmented Intelligence—Theory and Applications: Select Proceedings of MAI 2021 (pp. 85-90). Springer Singapore.

[21] Upadhyay, A., Basha, N. K., & Ananthakrishnan, B. (2023, February). Deep Learning-Based Yoga Posture Recognition Using the Y_PN-MSSD Model for Yoga Practitioners. In Healthcare (Vol. 11, No. 4, p. 609). MDPI.

[22] Zhang, T., Lian, J., Wen, J., & Chen, C. P. (2023). Multi-Person Pose Estimation in the Wild: Using Adversarial Method to Train a Top-Down Pose Estimation Network. IEEE Transactions on Systems, Man, and Cybernetics: Systems.

[23] Kaldarova, B., Omarov, B., Zhaidakbayeva, L., Tursynbayev, A., Beissenova, G., Kurmanbayev, B., & Anarbayev, A. (2023). Applying Game-based Learning to a Primary School Class in Computer Science Terminology Learning. In Frontiers in Education (Vol. 8, p. 26). Frontiers.

[24] Choi, J. H., Lee, J. J., & Nasridinov, A. (2021, March). Dance self-learning application and its dance pose evaluations. In Proceedings of the 36th Annual ACM Symposium on Applied Computing (pp. 1037-1045).

[25] Ke, L., Chang, M. C., Qi, H., & Lyu, S. (2022). DetPoseNet: Improving Multi-Person Pose Estimation via Coarse-Pose Filtering. IEEE Transactions on Image Processing, 31, 2782-2795.

[26] Sharma, H., Tickoo, A., Shrivastava, A. K., & Khan, U. (2023). Human Pose Estimation Using Artificial Intelligence. In Applications in Reliability and Statistical Computing (pp. 245-270). Cham: Springer International Publishing.

[27] Echeverria, J., & Santos, O. C. (2021). Toward modeling psychomotor performance in karate combats using computer vision pose estimation. Sensors, 21(24), 8378.

[28] Ramya, H. R., Vikram Nag, R. C., & Pramod Pavan Krishna, D. K. (2021). Machine-Learning Technique For Camera-Based Monitoring And Evaluation Of Yoga Posture. NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO, 1091-1098.

[29] Ranasinghe, I., Yuan, C., Dantu, R., & Albert, M. V. (2021, December). A Collaborative and Adaptive Feedback System for Physical Exercises. In 2021 IEEE 7th International Conference on Collaboration and Internet Computing (CIC) (pp. 11-15). IEEE.

[30] Setiyadi, S., Mukhtar, H., Cahyadi, W. A., Lee, C. C., & Hong, W. T. (2022, December). Human Activity Detection Employing Full-Type 2D Blazepose Estimation with LSTM. In 2022 IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob) (pp. 1-7). IEEE.

[31] Omarov, B., Suliman, A., Tsoy, A. Parallel backpropagation neural network training for face recognition (2016) Far East Journal of Electronics and Communications, 16 (4), pp. 801-808. doi: 10.17654/EC016040801

[32] Jin, Y., Mishkin, D., Mishchuk, A., Matas, J., Fua, P., Yi, K. M., & Trulls, E. (2021). Image matching across wide baselines: From paper to practice. International Journal of Computer Vision, 129(2), 517-547.

[33] Chen, S., Wang, Z., & Prisacariu, V. (2021, December). Direct-PoseNet: absolute pose regression with photometric consistency. In 2021 International Conference on 3D Vision (3DV) (pp. 1175-1185). IEEE.

[34] CR, P. K. (2021). Automized Driver Personalization using Computer Vision. SAE International Journal of Advances and Current Practices in Mobility, 4(2021-26-0032), 729-733.

[35] Raju, K. (2022). Exercise detection and tracking using MediaPipe BlazePose and Spatial-Temporal Graph Convolutional Neural Network (Doctoral dissertation, Dublin, National College of Ireland).

[36] Diaz, R. G., Laamarti, F., & El Saddik, A. (2021). DTCoach: your digital twin coach on the edge during COVID-19 and beyond. IEEE Instrumentation & Measurement Magazine, 24(6), 22-28.

[37] Moon, G., Chang, J. Y., & Lee, K. M. (2019). Camera distance-aware top-down approach for 3d multi-person pose estimation from a single rgb image. In Proceedings of the IEEE/CVF international conference on computer vision (pp. 10133-10142).

[38] Yamao, K., & Kubota, R. (2021, October). Development of human pose recognition system by using raspberry pi and posenet model. In 2021 20th International Symposium on Communications and Information Technologies (ISCIT) (pp. 41-44). IEEE.

[39] Bhowmik, A., Gumhold, S., Rother, C., & Brachmann, E. (2020). Reinforced feature points: Optimizing feature detection and description for a high-level task. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 4948-4957).

[40] Dsouza, G., Maurya, D., & Patel, A. (2020, November). Smart gym trainer using Human pose estimation. In 2020 IEEE International Conference for Innovation in Technology (INOCON) (pp. 1-4). IEEE.

[41] Toshpulatov, M., Lee, W., Lee, S., & Haghighian Roudsari, A. (2022). Human pose, hand and mesh estimation using deep learning: A survey. The Journal of Supercomputing, 78(6), 7616-7654.

[42] Morar, A., Moldoveanu, A., Mocanu, I., Moldoveanu, F., Radoi, I. E., Asavei, V., ... & Butean, A. (2020). A comprehensive survey of indoor localization methods based on computer vision. Sensors, 20(9), 2641.

[43] Sultanovich, O. B., Ergeshovich, S. E., Duisenbekovich, O. E., Balabekovna, K. B., Nagashbek, K. Z., & Nurlakovich, K. A. (2016). National Sports in the Sphere of Physical Culture as a Means of Forming Professional Competence of Future Coach Instructors. Indian Journal of Science and Technology, 9(5), 87605-87605.