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Original Article

Automated Monitoring of Gym Exercises through Human Pose Analysis

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Abstract - *This study offers a game-changing approach that combines techniques and exercises to ensure accuracy and injury-free performance in all activities, including squats and push-ups. The main goal is to teach proper structure and body posture to reduce injuries while keeping the body strong and having fun. The preparation process has an easy-to-use interface that makes repetitions and exercise preparation tangible. This is much newer than fitness tracking. Consider a system that tracks reps and provides quick feedback as you perform the exercise. Teach users to maintain good posture and reduce the risk of injury by receiving real-time alerts. This work explores the complexities of self-tracking, push alerts and reports, turning every activity into an efficient and mindful one. With 20 different exercises targeting different muscle areas and representative groups, the system will get even better with future mode notifications. To improve performance and safety, the module will give an alert on the screen if the user's body is faulty. The device uses powerful machine learning algorithms and powerful camera-based prediction technology to provide users with instant feedback on poses and techniques. The proposed platform has the potential to transform the energy industry by changing behavior and improving the safety and effectiveness of exercise. It is a useful tool for anyone who wants to improve their body and health.*

Keywords - *Fitness technology, Personalized workouts, Real-time feedback, Social motivation, Fitness companion.*

1. Introduction

Human Pose Estimation has become an important tool in the proliferation of technological developments, with its widespread use in human prediction, motion analysis, visualization and human-machine interfaces. This project solves the complex task of 3D joint estimation of the human body by analyzing images or videos and estimating human poses.

3D human pose estimation is becoming increasingly popular in the field of computer vision due to its important applications in robotics, human motion analysis, and human-computer interactions. This study provides an additional feature by providing detailed information focusing on deep learning processes, laying a foundation for a better understanding of this game-changing phenomenon.

By using this technology to track the movements of gym players, this research offers a useful way to move beyond the theoretical limitations of human body measurements. The main goal is to change traditional sports to be safe and injury-free. The proposed system provides the best of both worlds, not just software; it becomes a virtual training partner. This personal assistant is designed to improve overall health, personalize travel, and instantly engage with customers. For this question, the work of a virtual personal trainer is crucial. It goes beyond the exercise routine by tracking repetitions, making sure each exercise is performed correctly, and tailoring the training to each user's needs.

For this purpose, physical body sensing technology is used to accurately record the head, shoulders, elbows, hips, knees and feet. The technology tracks the training process and modifies activities through a complete analysis of the body and movements.

The need is designed as a solution that respects and acknowledges individual achievements. This is not just a rep counter; It is a virtual personal trainer that helps users achieve their health goals and gives advice for their efforts. This vision is about healing the outer body but also building strength, confidence and personal growth.

In fact, the conceptual system is human-centered. This acknowledges the challenges of daily living, the difficulty of planning physical activity, and the importance of sustained motivation. The system aims to create a society with more than the best technology by transforming the purpose of the body into unity. People can gather here to celebrate their achievements.

Let us start with the fitness method thatexpertly combines technology, personal guidance and a sense of community. The presented method is more than a tool; This is a revolutionary way to exercise; It is a method of enjoying every exercise, appreciating personal achievements and representing yourself with a strong body and health.

2. Literature Survey

Wang et al. (2021) [1] tackled the problem of estimating a human body's 3D joint location from pictures or movies. Deep learning-based approaches are highlighted in this thorough literature review, along with their benefits and drawbacks, especially as they relate to robotics, human motion analysis, and human-computer interaction. The study offers a thorough examination of widely used benchmark datasets, giving readers a comprehensive picture of the field's advancements and difficulties.

Bertugli et al. (2021) [2] outlined a generative architecture for multi-future trajectory prediction in crowded situations called AC-VRNN. To estimate potential moving directions and past movements, the system uses Conditional Variational Recurrent Neural Networks (C-VRNN) in conjunction with prior belief maps and graph-based attention techniques. Robust tests conducted on various datasets showcase the efficacy of the model, surpassing numerous cutting-edge techniques, rendering it advantageous for socially-aware robots and intelligent transportation systems.

Schlett et al. (2021) [3] offered a method based on deep learning for improving the facial depth information found in individual photos. Two major obstacles to 3D human pose estimation are depth ambiguities and the scarcity of wild datasets, which are addressed by this method. The work contributes to a better understanding of the field by offering a complete literature analysis of deep learning techniques, highlighting the benefits and drawbacks of various approaches.

Kocabas et al. (2019) [4] suggested epipolar pose, a self-supervised learning technique that does not require a large amount of 3D ground-truth data for 3D human pose estimation. During training, the approach produces 3D poses and camera geometries by utilizing epipolar geometry to estimate 2D poses from multi-view photos. On benchmark datasets, the efficacy of epipolar pose has been proven, yielding state-of-the-art performance among weak/self-monitoring techniques. In order to evaluate pose plausibility, the study also provides a Pose Structure Score (PSS).

Chen et al. (2021) [5] outlined a novel method for estimating the 3D human position from films by dividing the work into two parts: predicting the length and direction of the bones. This approach provides an anatomically informed understanding of human poses by concentrating on particular bones within the human skeleton. The study also highlights how crucial temporal consistency is in video sequences, which broadens the technique's application. Its potential in fields including action recognition, motion capture, and human-computer interface is demonstrated by experimental results.

Nadeem et al. (2020) [6] created a system that uses artificial neural networks to track and identify human actions based on body part detection. Using the KTH and Weizmann human action datasets, the study detected 12 body parts to identify complicated actions, which were then fed into an artificial neural network. High accuracy was demonstrated by the results, confirming the method's suitability for use in e-learning, smart monitoring, health fitness programs, and the identification of deviant behavior.

Verma et al. (2021) [7] created a responsive web application to let faculty, students, and alumni communicate with one another within the campus community. The development approach with Django for the back end, React JS for the front end, and a database for data management is described in depth in the paper. It also provides a thorough tutorial on creating web apps with machine learning capabilities by integrating machine learning for text analysis using Scikit-Learn and deploying using Flask.

Pavlo et al. (2019) [8] outlined a fully convolutional model for 3D human posture estimation from video that is based on extended temporal convolution. The paper presents back-projection, a semi-supervised learning method that makes use of unlabeled video data to increase accuracy. On benchmark datasets like HumanEva-I and Human3.6M, the model demonstrated notable improvements in performance, with an average per-composite position error reduction of 11% in the supervised context.

Ma et al. (2022) [9] suggested Direct Dense position (DDP), a novel method for estimating dense human position. DDP predicts the instance mask and the global IUV representation independently, in contrast to earlier techniques that mainly rely on the mask R-CNN. By minimizing runtime and transient shocks, this method achieves computing efficiency and competitive accuracy. This approach provides a solid answer for body reconstruction and human action identification, and it works especially well in video sequences.

Liu et al. (2022) [10] introduced the Adapted Human Posture (AHUP) method for estimating human posture in 3D monocularly without the need for real 3D pose data. AHuP uses Skeleton Pose Adaptation (SPA) and Semantically Aware Adaptation (SAA) to handle domain shift concerns in training and test data. Despite utilizing no real 3D posture data, this method outperforms state-of-the-art models trained on large real 3D datasets. To help with this research, a new synthetic human dataset called ScanAva+ is also introduced.

3. Materials and Methods

Cleverly designed solutions combine advanced technology with user-friendly design. The foundation of the solutions is carefully designed to ensure customer satisfaction and unmatched performance. The sustainability of the application is essential. The front end of the system is an intuitive front end built with ReactJS [15]. With easy navigation, the interface makes healthcare accessible to everyone. Flask powers the backend for secure and fast processing of user data. The reliable MongoDB database can store and organize many data sources. FastAPI acts as a bridge, allowing many products to communicate easily.

The graphic design clearly demonstrates the multi-layered and complex process of searching for a good gym site. The front end is a beautiful user interface designed to engage and interact with customers. The API layer is important to facilitate data transfer and communication between the system and other systems. The main function of the middle layer is to collect information from different sources, such as joints and visual inputs, and this is important for determining the truth. The body's ability to calculate angles and determine geographic areas increases the accuracy of tracking the user's body. Flask is a powerful web framework that manages the web and acts as a bridge between multiple layers. Using other libraries, such as OpenCV can improve the performance of the system.

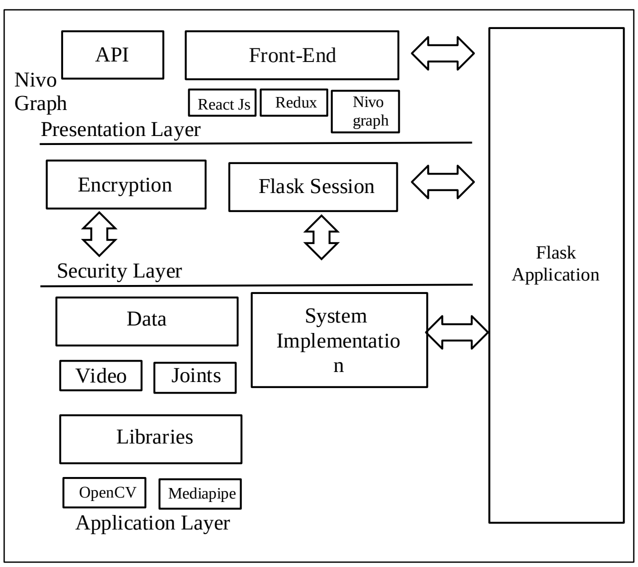

Fig. 1 System architecture

Important diagrams such as schematic diagrams, state diagrams, system diagrams and functional diagrams have been carefully placed within the text to enhance the reader's understanding. This conceptual organization will help the reader understand the explanation more clearly by visualizing the technique. Technical accuracy and customer support are key to the approach. The method uses the MediaPipe library [17] to accurately identify and track exercises, providing rapid feedback to the user. Modern algorithms are used in the system and explained with flow charts so that both engineers and users can understand the complex operating principles.

Envisioning a combination of technology and user-focused devices, the proposed system promises to revolutionize the way of exercising. This is not just a system; It is a smart combination combining efficiency, simplicity and creativity.

The system should follow these instructions to create a useful AI gym tracker: First, OpenCV should be installed on the system and configured correctly. This allows the system to accurately predict using the MediaPipe library and the connected webcam [16, 17]. Second, the system must be able to extract the joint from recognized poses. Third, the system must use Numpy and trigonometry to calculate the angles of the joints to determine the accuracy of each movement. Additionally, the system needs to set a target number and notify the user when the target is reached. The system should warn users if they fail repetitions or adopt incorrect postures. Finally, the system should use intelligent resources to instantly and accurately calculate the user's repetitions in order to provide an overall evaluation of the exercise [18].

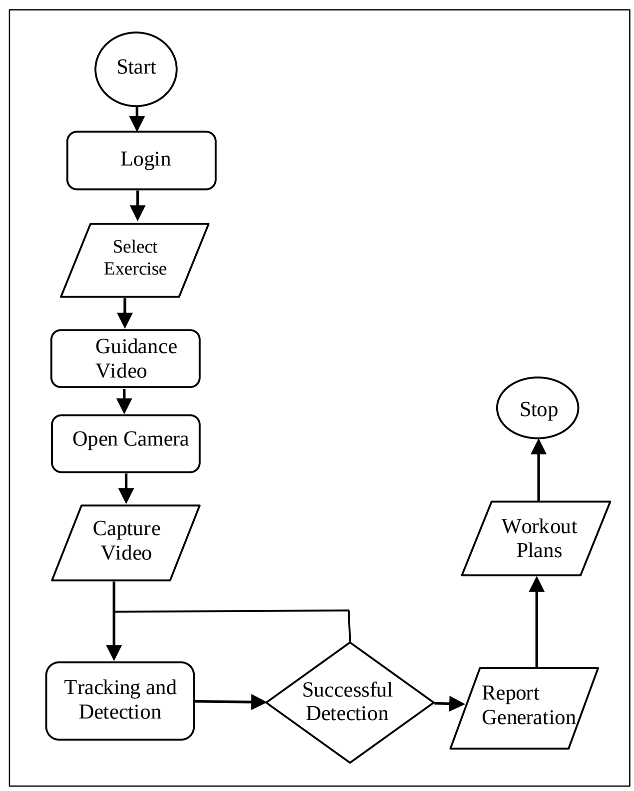

Fig. 2 System flowchart

The ability to combine equipment with exercise to provide users with an engaging, informative and safe workout. The flowchart that is part of the proposal describes a seamless, technology-enabled application for users. To provide software development information, the system will show users to enter from the “Start” node. Once successfully logged in, they can choose a workout from a variety of options. This is the part where user involvement gets really exciting, as Open Camera gives the software access to the device’s camera and configures it for the next game. After capturing the video, the application enters the main phase called “search and discovery” and instantly identifies the user’s body and body. Thanks to this study, consumers will be able to measure the effectiveness of their exercises based on the information generated.

Once the exercise is finished, the user can decide whether to continue or not by accessing the option. Finally, the mapping is completed, and the end node shows the user’s exercise. This system flow chart effectively captures the system concept. To calculate the angle between the three points detected in the video, the system uses the following equation:

Let, A as the points represented by coordinates (x_a, y_a)
B as the points represented by coordinates (x_b, y_b)
C as the points represented by coordinates (x_c, y_c).

$$radian = \left(arctan\left(\frac{(y_c - y_b)}{(x_c - x_b)}\right) - arctan\left(\frac{(y_a - y_b)}{(x_a - x_b)}\right)\right) \quad (1)$$

If the angle is greater than 180, subtract it from 360 to get a smaller angle. The first arctan function calculates the arctangent of the slope of the line segment from point B to point C. It gives the angle formed by this line segment with the positive x-axis. Similarly, the second arctan function calculates the arctangent of the slope of the line segment from point B to point A, giving the angle formed by this line segment with the positive x-axis. The difference between these two arctangent values gives the change in angle between the two line segments. However, simply subtracting them might give an angle greater than π radians (180 degrees), and it does not consider the direction of rotation. To handle this, the system takes the absolute value of the difference and converts it to degrees by multiplying it by $\frac{180}{\pi}$. This gives the angle in degrees. The equation is given below:

$$angle = \left| radian \times \frac{180}{\pi} \right| \quad (2)$$

The solution is based on an innovative and carefully designed strategy to improve user experience. By leveraging the power of the MediaPipe library [17], the model cannot achieve uniformity in prediction, which is important for fitness tracking. The system can accurately record user activity using complex algorithms and deep learning. MediaPipe [17], the basis of the model, provides accurate pose evaluation on the fly. Its user-friendly interface and powerful algorithms transform user actions into digital data, creating a better relationship between users and the programs. Thanks to this integration, all activities and all aspects are captured with the highest accuracy. The system incorporates a Convolutional Neural Network (CNN) to improve the accuracy and stability of the model. This complex neural network architecture explores the complexity of human movement by discovering different patterns that the human eye may miss. In addition to recognizing gestures, the system can also use CNN to analyze the accuracy of the user’s body.

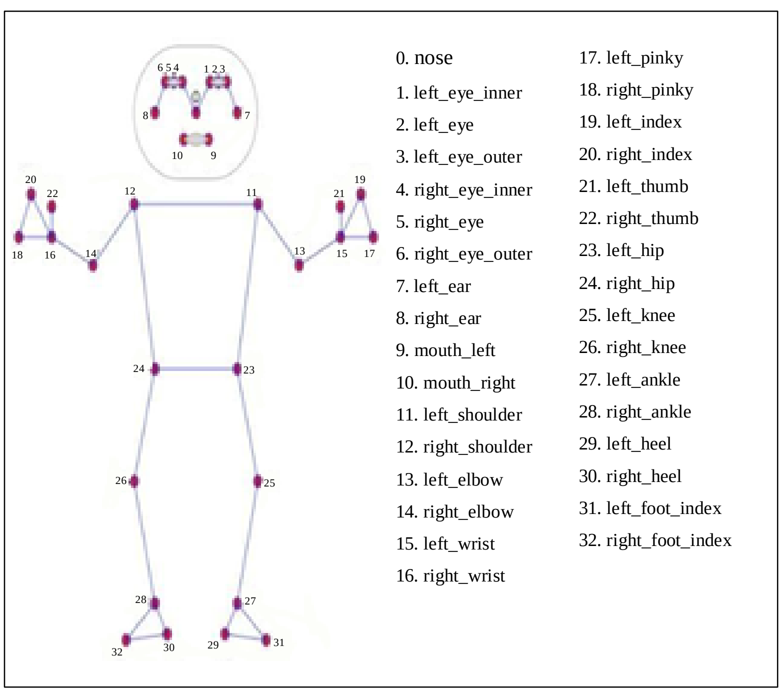

Fig. 3 Pose detection image using mediapipe library

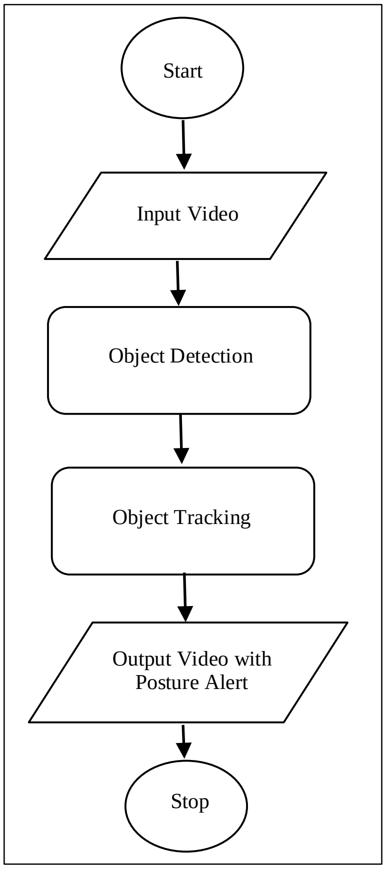

Fig. 4 Algorithm flowchart

Figure 4 shows the given algorithm flowchart, which outlines a streamlined process for producing warnings and tracking posture in real-time. The "Start" node represents the beginning and subsequent execution of the algorithm. The first stage, called "input video," involves feeding the algorithm a video stream typically captured during physical activity or exercise. The film formed the basis for subsequent research. In the "object detection" phase, the algorithm finds and identifies important objects or locations in the video image.

For body care, this step is particularly important because it allows the algorithm to identify the user's body or other parts of the body. At this point, the Search for Items section opens, and the tracking of items found over time begins. Thanks to this type of tracking, the program can track changes and movements in the body throughout the movie. The program constantly evaluates the user's posture and posture while processing video files. If it detects a difference or problem with the body, it causes "body-stimulated video output".

These videos may have visual cues that alert viewers to depression and guide how the body can heal. When the algorithm reaches the "End" node, the behavior tracking process ends [19, 20].

In short, the work explores the combination of two state-of-the-art technologies (MediaPipe [17] and CNN) to create a model that reimagines body tracking. The plan enables users to achieve their health goals with precision and confidence through accurate and immediate feedback.

The new system is based on technology and user-centric devices and reaches new heights with the integration of instant recommendations and notifications. Imagine a sport where not only your body is tracked, but the system provides instant notification and feedback about your movements. This improvement ensures that each repetition not only counts but is performed correctly, reducing the risk of injury and improving exercise performance.

The system always tries to be a fitness partner, so the system has included tips and reminders to improve your workouts. These features are well integrated with the system-based design. Users can now get real-time on-screen alerts as they interact with the program, which will walk them through proper posture and point out areas where they need to improve. It turns working out into a dynamic, engaging fitness journey rather than just a conventional exercise.

Incorporating exercises such as biceps curls, lateral shoulder raises, and squats into the project using MediaPipe for correct pose estimation involves defining the correct form for each exercise and using keypoint detection to ensure the user's form matches the expected pose.

For the Bicep curls exercise, the key points to detect are - Shoulder, elbow, and wrist alignment. Moreover, the condition that the elbow angle (should decrease and then increase during the curl). Using MediaPipe to detect key points at the shoulder, elbow, and wrist. Measuring the angle at the elbow to ensure it decreases during the curl and increases when lowering the weights.

For the Lateral Shoulder exercise, the key points to detect are shoulder, elbow, and wrist alignment. The condition is that the arm position relative to the torso (should be raised to shoulder height) and a slight bend in the elbows. Using MediaPipe to detect key points at the shoulder, elbow, and wrist. And then monitor the height of the wrists to ensure they reach shoulder level ensuring that the arms are raised in a controlled manner and not above shoulder height.

For the squat exercise, the key points to detect are hip, knee, and ankle alignment. The condition is that the knee angle (should decrease during descent and increase during ascent). Using MediaPipe to detect key points at the hip, knee, and ankle. Then, measure the knee angle to ensure it decreases when lowering and increases when rising along with monitoring the alignment of the knees with the toes to prevent the knees from caving in or out.

These updates demonstrate the commitment to empowering users and ensuring that all fitness enthusiasts, regardless of their experience, can enjoy encouraging community-wide benefits. Based on technologies like CNN and MediaPipe, the technology helps you improve your skills while accurately tracking your movements. It is important to add motivation and data to your workouts, not just focus on numbers. The system uses a variety of health care methods to make each exercise a fit practice that keeps you safe and thrives first.

4. Results and Discussions

The system created has an easy-to-use user interface for recommendations that allows users to choose the exercises they want to do after determining the exact body shape they want to show off. With this feature in mind, users can customize their daily activities to suit their specific goals. Rather than asking users to explore various activities, the program suggests activities based on their ideas for the specific body they choose. Users can quickly see visuals of each exercise when they click on the YouTube video link that accompanies this tutorial. These features make it easier to plan workouts, improve the overall user experience, and allow people to make better decisions about their training plans.

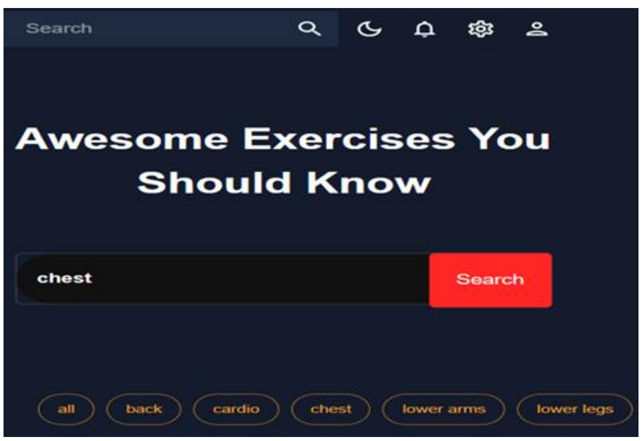

Fig. 5 Exercise search UI

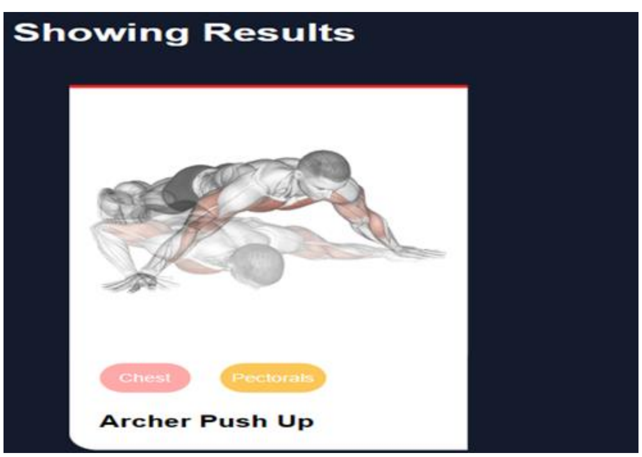

Fig. 6 Exercise search results

The system's web-based gym activity tracking system provides excellent results in real-time tracking as well as workout guides. During the course, users can use this tool to track their progress. Using monitoring tools, the project provides the customers with access to real-time information about their installations, agents, and other security measures. Users can instantly adjust their training to ensure they are in the training zone their team needs and get the most out of their training with the tool that truly searches for real-time and quick tips. Real-time progress tracking makes training more efficient and successful by improving safety and helping people understand how hard they are working.

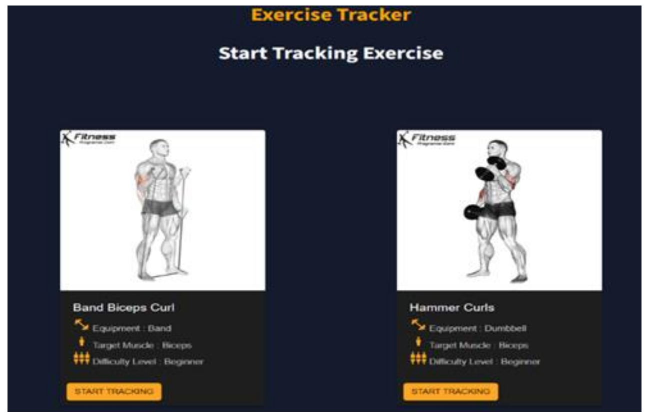

Fig. 7 Exercise selection cards for monitoring

Fig. 8 Feedback for the incorrect move of biceps exercise

Fig. 9 Feedback for the incorrect move of biceps exercise

Fig. 10 Feedback for the incorrect move of triceps exercise

Fig. 11 Feedback for the incorrect move of lateral raises exercise

This website for logging workouts at the gym gives users a way to see and achieve their fitness goals by displaying progress. How much weight do they use, and how much rest do they get? Through rigorous analysis and ease of use, this information allows people to track their physical development over time. Users can set achievement goals, track progress, chart results, and develop customized training plans. This method of fast-tracking not only encourages accountability and motivation but also encourages a sense of progress as users can instantly see their progress.

To understand the effectiveness of the plan, many important factors were taken into account when evaluating tracking accuracy and non-repetition during movement. The algorithm does an excellent job of comparing its calculations to manual analysis or the initial measurement, the previously measured model.

The particular examples of accuracy seen in the tracking of the copies show his confidence in this important aspect. The effectiveness of the system in providing users with immediate feedback on accurate repeatability is verified. This includes how long users are rewarded for maintaining perfect form.

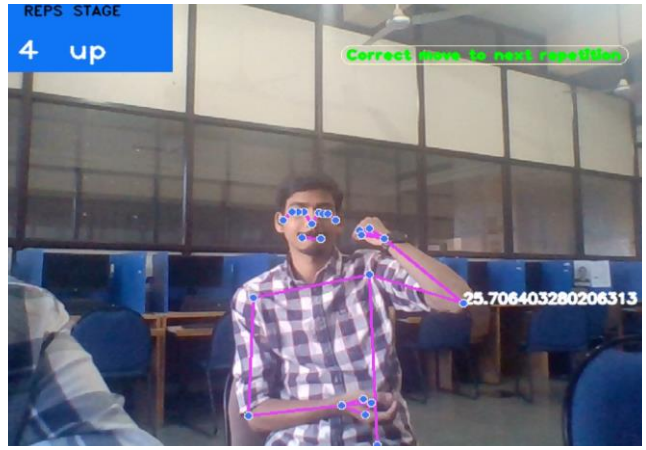

Fig. 12 Feedback for the correct move of biceps exercise

Fig. 13 Feedback for the correct move of biceps exercise

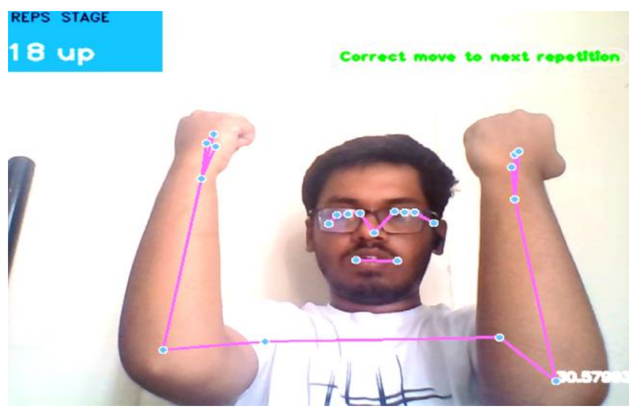

Fig. 14 Feedback for the correct move of forearms exercise

The aim is to use the angle as an important measure of measurement accuracy and repeatability when applying the proposed method. The technology provides specific accuracy in the use of angles, providing important information about the user's body by showing how accurate each repetition is. Focus on recording changes in the accuracy of the proposed system to evaluate its accuracy in monitoring joint angles during operation.

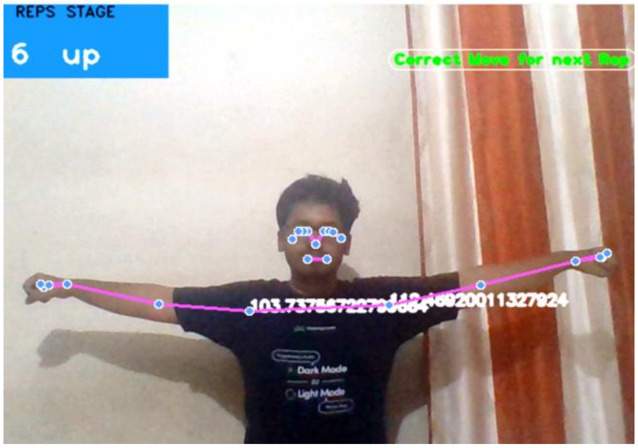

Fig. 15 Feedback for the correct move of lateral raises exercise

In terms of accuracy, the system is efficient and can detect small changes in joint angles, which is necessary to distinguish correct and incorrect repetitions. Creating customized angle profiles for an individual exercise also demonstrates the complexity of the system by explaining the need for many aspects of cooperation necessary for success. Thanks to this special application, the system shows that it is able to track and measure the accuracy of every detected movement, thus guaranteeing the measurement.

The most important thing that allows the user to understand the potential customer well is the use of the user interface to find the joint. These observations show that the system is effective at measuring angles and also improves user experience and compatibility. It also has positive effects on user interaction and appropriate behavior. The system has proven its ability to simultaneously detect and report repeated errors, provide information about the stability of its algorithm, and provide feedback for future iterations. Review learning and development.

To do this, it is necessary to evaluate how they respond to suggestions from the system and identify conditions that show that they have a better success correction result while reducing errors. As users can see regarding the correction instructions, the system improves the exercise. By demonstrating the ability to detect and report repeated errors simultaneously, the system has demonstrated its ability to provide information about the stability of its algorithm and provide feedback for future iterations. Exercise performance was improved by the system, as seen by the way users interacted with the corrected feedback.

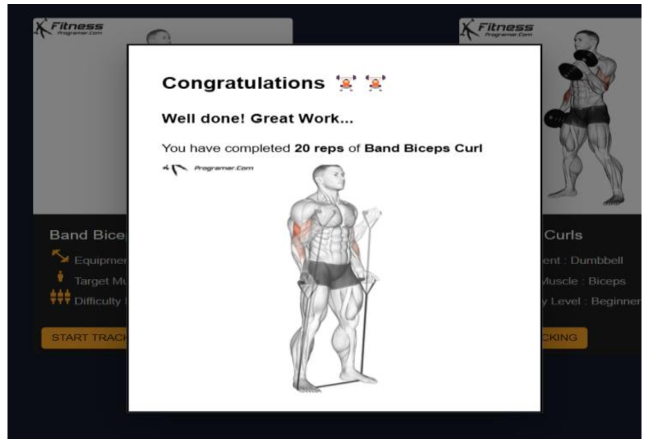

Fig. 16 Congratulations banner after successful workout completion

5. Conclusion

This new idea will enhance safety and productivity in physical activities as well as increase the overall health and well-being of their populations. Financial analysis is a major development in education, sports, health care, and workout, among other human activities. The ability to detect and measure the human body and body movements in real-time creates new opportunities to improve user communication and human-machine communication, as well as ensure proper healing of the body.

In addition to offering simple exercises, it encourages users to follow a safe and healthy lifestyle. The system discoveries have not only revolutionized the effectiveness and safety of exercise but have also led to significant advances in exercise, training, hygiene and health. Once the existing feedback is complete, user engagement will increase further, and users will be able to get instant advice on security and better performance.

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