Exercise Posture Correction Application: A comprehensive review

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Abstract— **People often learn to perform exercises with proper form through personal research or guidance from experienced individuals, such as personal trainers. However, incorrect form still accounts for 33.3% of exercise-related injuries. Studies have shown that having a personal trainer significantly reduces injury rates. Despite this benefit, factors such as cost, scheduling conflicts, and the preference for training alone often limit access to personal trainers. Given that 91% of UK adults own a smartphone, a mobile app could potentially serve as an alternative to a personal trainer. This paper explores solutions proposed by various studies on Exercise Form Correctors utilizing convolutional neural networks (CNN) and other machine learning techniques. It provides an in-depth review of these studies, including insights into the tools, technologies, and algorithms employed, as well as their accuracy. Additionally, it discusses the implementation of an Exercise Posture Correction application developed using Flutter and OpenCV. The paper also highlights future trends and research opportunities, emphasizing the potential benefits of larger, more diverse datasets and the integration of wearable sensors with machine learning algorithms. Finally, it summarizes the key findings from the reviewed studies.**

Keywords— Exercise Form Corrector, Convolutional Neural Network (CNN), Machine Learning, OpenCV, Exercise Applications

I. INTRODUCTION

In 2020, the U.S. Consumer Product Safety Commission (CPSC) reported over 400,000 exercise equipment-related injuries, with many linked to improper form or misuse. Research published in the *Journal of Sports Science and Medicine* highlighted that 30-50% of weightlifting injuries are caused by incorrect form. Similarly, a study in the *Orthopedic Journal of Sports Medicine* noted a rise in yoga- related injuries, attributing major causes to poor form and overuse. In 2017 alone, yoga-related incidents accounted for approximately 5,500 emergency department visits in the U.S. Maintaining correct exercise form is critical to prevent injuries and achieve optimal results. However, without proper guidance, many individuals risk performing exercises incorrectly, which can result in inefficiencies or long-term physical harm.

Types of Injuries

Sprains and Strains: Ligament sprains and muscle strains are frequently caused by incorrect movement patterns and overextension during exercises.

Joint Injuries: Improper form can place excessive stress on joints, leading to conditions like tendonitis, bursitis, and joint dislocations.

Figure 1 depicts the general system architecture for an Exercise Form Corrector. The system includes several components: a user profile, a workout tracker that monitors the user's exercise form in real time, a BMI calculator, and a meal planning feature tailored to the results of the BMI calculator. This integrated approach helps users maintain proper exercise form, track their progress, and receive personalized dietary recommendations to support their fitness goals.

The challenges associated with exercise form correction and pose estimation have seen significant advancements, largely due to the development of deep learning techniques and the availability of publicly accessible datasets. This survey summarizes existing research, offering up-to-date insights while highlighting potential directions for future exploration. Similar to other notable surveys [1]–[3], this paper provides a comprehensive overview of the general concepts underlying human pose estimation.

This project aims to create an Exercise Form Corrector Application that leverages Convolutional Neural Networks (CNNs) to monitor and improve users' exercise form. The application will process video input of users performing exercises such as squats, push-ups, and lunges, analyzing their movements in real-time. It will provide instant feedback to help users align their actions with proper form guidelines, reducing the risk of injury and enhancing exercise efficiency.

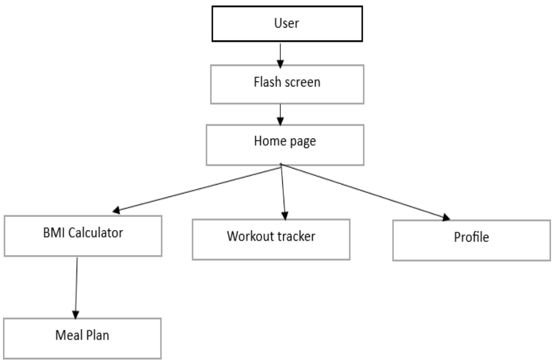

FIGURE. 1. System Architecture of application.

II. REVIEW OF LITERATURE

[1] PifPaf: Composite Fields for Human Pose Estimation by Sven Kreiss, Lorenzo Bertoni, Alexandre Alahi, 2019: They introduce a novel bottom-up approach for multi-person 2D human pose estimation, designed to perform effectively in urban mobility scenarios like self-driving vehicles and delivery robots. This method focuses on identifying human poses in densely populated environments. It incorporates the PifPaf technique, which uses a Part Intensity Field (PIF) to detect body parts and a Part Association Field (PAF) to link these parts into cohesive human poses. The method also integrates Mask R-CNN for additional analysis. Comparative evaluations of Average Precision (AP) revealed that PifPaf outperforms Mask R-CNN in accuracy.

[2] POSE ESTIMATION AND ACTION RECOGNITION
IN SPORTS AND FITNESS by Parth Vyas, San Jose State University, 2019:
An alternative method for delivering workout feedback has been developed, focusing on training multiple models specific to various exercises rather than analyzing key points and angles. These models are applied to both real-time and pre- recorded videos to provide users with repetition counts. The approach utilizes the PennAction dataset, derived from the study "Strongly-supervised Representation for Detailed Action Understanding," which contains a collection of workout images. Convolutional neural networks (CNNs) are employed to train these models effectively.

[3] Exploring Rare Pose in Human Pose Estimation by JIHYE HWANG, JOHN YANG, AND NOJUN KWAK, (Senior Member, IEEE), 2020:
This study introduces a new criterion for identifying rare pose samples and proposes techniques to improve pose estimation for these unique poses, which represent a small subset of a dataset. The researchers utilized K-means clustering with defined distance thresholds to detect and classify these outlier poses effectively. To enhance model training on rare poses, they developed two data augmentation techniques, DRP and ASRP, along with a weighted loss correction method (WLCD). Combining these augmentation methods with WLCD significantly improved the detection of rare poses. Experiments conducted on the COCO and MPII datasets demonstrated the effectiveness of these approaches, with DRP+WLCD and ASRP+WLCD yielding notable improvements in rare pose estimation.

[4] The Progress of Human Pose Estimation: A Survey and Taxonomy of Models Applied in 2D Human Pose Estimation by TEWODROS LEGESSE MUNEA, YALEW ZELALEM JEMBRE, HALEFOM TEKLE WELDE GEBRIEL, LONGBIAO CHEN, CHENXI HUANG, AND CHENHUI YANG, 2020:
This survey provides a comprehensive overview of research in 2D human pose estimation, addressing knowledge gaps and summarizing developments in the field. It categorizes pose estimation techniques into single-person and multi-person methods, depending on the number of individuals being analyzed. The survey also explores various methodologies, applications, and challenges associated with human pose estimation. It highlights DeepPose as a pioneering study that applied deep learning to this domain, utilizing an AlexNet- based architecture with five convolutional layers, two fully connected layers, and a softmax classifier. Additionally, it reviews other machine learning models and techniques, such as R-CNN, Fast R-CNN, FPN, Faster R-CNN, and Mask R- CNN, which have been used as foundational architectures in subsequent pose estimation research.

[5] Deep Learning for Fitness by Mahendran N, Indian Institute of Technology Tirupati, Andhra Pradesh, India, 2021:
They introduce Fitness Tutor, an application

developed to assist users during workouts by analyzing their body posture through deep learning-based pose estimation. The app features an animated, realistic model that demonstrates correct exercise techniques. To enhance its accuracy, it utilizes an online platform to retrieve posture images for comparison, sourcing poses from curated YouTube videos. The application employs the PoseNet model from the ml5.js library, with p5.js facilitating the execution of PoseNet and the computation of the results.

[6] LogRF: An Approach to Human Pose Estimation Using Skeleton Landmarks for Physiotherapy Fitness Exercise Correction by ALI RAZA, AZAM MEHMOOD QADRI, IQRA AKHTAR, NAGWAN ABDEL SAMEE, AND MAALI ALABDULHAFITH, 2023:
This study presents an efficient artificial intelligence approach for human pose estimation in physiotherapy and fitness exercises. It utilized a multi-class exercise dataset based on human skeleton pose data, comprising 2,701 rows and 133 columns, where each row represents a specific exercise and each column captures various details of the human skeleton model. The study applied several algorithms, including Random Forest, Logistic Regression, Gated Recurrent Unit (GRU), and Hyperparameter Optimization. The resulting accuracies for these models were as follows: Random Forest achieved 0.998, Logistic Regression scored 0.990, GRU reached 0.997, and Hyperparameter Optimization resulted in 0.974.

[7] Multi-Person Pose Estimation Using Group-Based Convolutional Neural Network Model by SHUHENA SALAM AONTY, KAUSHIK DEB, MOUMITA SEN SARMA, PRANAB KUMAR DHAR AND TETSUYA SHIMAMURA, 2023:
This paper presents a human pose estimation approach utilizing a group-based convolutional neural network model. The method employs a bottom-up parsing strategy to extract skeletal key points from the human body. For training, cross-validation, and testing, the widely used MPII dataset is used. The process involves gathering the MPII dataset, training models using architectures like ResNet-50 and HRNet-w32, and evaluating the trained model. The results show that the proposed method achieves a mean average accuracy of 93%, which represents a 0.6% improvement over the accuracy of the previous method, which was 92.4%.

[8] CNN-LSTM Model for Recognizing Video-Recorded Actions Performed in a Traditional Chinese Exercise by JING CHEN, JIPING WANG, QUN YUAN, AND ZHAO YANG, 2023:
This study explores a motion recognition model designed to identify complex action sequences involved in the traditional Chinese exercise, Baduanjin. The researchers developed a hybrid model combining Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) to recognize these action sequences from video frames. Since no public image dataset for Baduanjin exists, they collected videos from 18 participants (11 men and 7 women), each performing the eight poses individually. The study tested a CNN-LSTM model using VGG16 to extract pose features from each frame, which were then processed by the LSTM module to capture the dynamics of the poses over time. The model achieved an impressive accuracy of 96.43% on the testing set.

[9] Form Check: Exercise Posture Correction Application by Morarjee Kolla, Phani Varma Gadiraju, Dhruvraj Tondanoorthy, 2024:
This paper introduces a deep learning model aimed at detecting incorrect postures and providing corrective guidance to improve safety and efficiency during exercises. The process begins with the user uploading a video (stored in a Google Drive folder), which is processed by a multi-person tracker. The tracker generates a .pickle file, which is sent to the Pose Estimator algorithm. This algorithm classifies the activity in the video, searches for the specific exercise in the dataset, and sends the result to the Posture Corrector. The Posture Corrector analyzes incorrect postures detected by the activity recognizer and creates a vector geometry plot on a 3D plane to assist in correction. The system uses You Only Look Once (YOLO) as the person tracker, VIBE for pose estimation, and Graph Convolutional Network (GCN)-based models for exercise classification and posture correction. Both the performed and corrected exercises are displayed visually. While most exercises are identified accurately, certain movements—such as proper squats, forward-bent squats, and shallow lunges—may have reduced accuracy due to subtle differences near the boundary between correct and incorrect forms.

[10] A Mobile-Phone Pose Estimation for Gym-Exercise Form Correction by Matthew Turner,

Kofi Appiah and Sze Chai Kwok, 2024:
This paper presents a system designed to detect incorrect exercise poses and provide corrective feedback based on identified anomalies. Real-time experiments were conducted using live video to assess the system's performance. Three exercises with varying complexity—bicep half-curls, lateral raises, and barbell squats—were chosen to evaluate the model in different scenarios. Videos for each exercise were recorded in an actual gym environment to ensure realistic background imagery was included in the tests. A DataHandler class was developed to load and store MPII Human Pose annotations (Andriluka et al., 2014), manage image loading, and perform preprocessing with the imgaug library (Jung, 2020). The model achieved an average PCKh@0.5 score of 0.927 for visible- only data and 0.844 when non-visible joints were included.

III. IMPLEMENTATION

The application will consist of a user-friendly UI developed in flutter. The next step is to train the model using OpenCV and python to detect incorrect form followed by the integration of model with flutter application and finally the testing of application for any bug

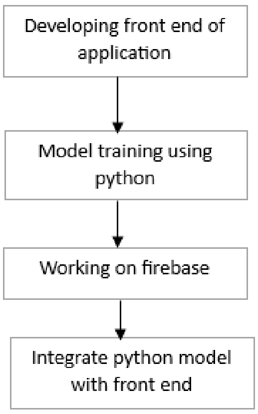

FIGURE 2. Work Flow of the system

IV. CHALLENGES

1. Interpretability of Models: Advanced models like artificial neural networks often operate as "black boxes," meaning their decision-making processes are not easily understood or interpreted, which can make debugging, trust-building, and refinement challenging.
2. Dataset Limitations: A limited dataset size and lack of diversity pose significant obstacles for training machine learning models. These limitations can lead to overfitting (where the model performs well only on training data but poorly on new data) and hinder the model's ability to generalize effectively to unseen scenarios.
3. Real-World Data Variability: Variability in real-world environments, such as changes in lighting, camera angles, or movement, can undermine the model's ability to maintain high performance when applied to live, real- world data, especially if the models are primarily trained on controlled, previously recorded media.

V. CONCLUSION

This review highlights the progress made in the application of machine learning (ML) and deep learning (DL) approaches in exercise and fitness, particularly in the context of form and pose estimation. While the results have shown effectiveness, there are still several challenges that need to be addressed, including interpretability issues, dataset limitations, and concerns related to real-world usability. The way forward calls for a stronger focus on developing more sophisticated algorithms, expanding existing datasets, and integrating additional technologies to enhance accuracy and relevance. The system we aim to develop will use video data, which currently has limited types, but can be expanded in the future. This system will help guide users in performing exercises correctly and prevent injuries. It will also feature a BMI calculator to suggest appropriate meal plans based on the user's body type.

VI. REFERENCES

[1] PifPaf: Composite Fields for Human Pose Estimation by Sven Kreiss, Lorenzo Bertoni, Alexandre Alahi, 2019

[2] POSE ESTIMATION AND ACTION RECOGNITION IN SPORTS AND FITNESS by Parth Vyas, San Jose State University, 2019

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JEMBRE, HALEFOM TEKLE WELDE GEBRIEL, LONGBIAO CHEN, CHENXI HUANG, AND CHENHUI YANG, 2020

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