Exercise Posture Correction System using Deep Learning Techniques

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In today's increasingly sedentary society, where technological advancements often lead to decreased physical activity, maintaining proper exercise posture is crucial to prevent injuries and maximize the benefits of physical activity. In response to this challenge, we propose an exercise posture correction system that utilizes deep learning models and an error detection algorithm to analyze and correct exercise posture in real-time. The system consists of a device with a camera and software, which incorporates pose estimation and human activity recognition models to assess posture and classify exercises. The error detection algorithm identifies key angles for each exercise class and provides feedback to the user. Our software, developed using Unity, provides a user-friendly interface for seamless integration into exercise routines. Testing results demonstrate the effectiveness of the system, with high accuracy and precision scores achieved in both pose estimation and activity recognition. This system offers a promising solution to promote correct exercise posture, mitigate injury risks, and enhance the overall exercise experience.

Keywords—Posture Correction, Deep Learning, Pose Estimation, Human Activity Recognition, Injury Prevention, Unity

I. INTRODUCTION

Exercise is a cornerstone of a healthy lifestyle, contributing to physical fitness, mental well-being, and quality of life. From cardiovascular workouts to strength training and flexibility exercises, the benefits of regular physical activity are well-documented and far-reaching. Engaging in exercise not only helps maintain a healthy weight and improve cardiovascular health but also boosts mood, reduces stress, and enhances cognitive function.

In today's sedentary society, where technological advancements often lead to prolonged periods of sitting and decreased physical activity, prioritizing regular exercise is more important than ever. Whether it's a brisk walk, a yoga session, or a gym workout, finding enjoyable and sustainable ways to stay active is key to promoting longevity and vitality.

Although exercise is important, It is also important during exercise to have proper breathing and good posture, this helps the body to function and will cut muscle strain and injury [1]. But many individuals struggle to maintain correct posture, leading to suboptimal results and increased risk of injury. Proper body posture has been associated with a reduction in incidence of injuries [2]. This correlation shows the importance of correct posture in mitigating the risk of exercise-related injuries.

In response to the problem that we encountered, we propose an exercise posture correction system that aims to analyze and correct exercise posture to help cut the risk of injury during exercise.

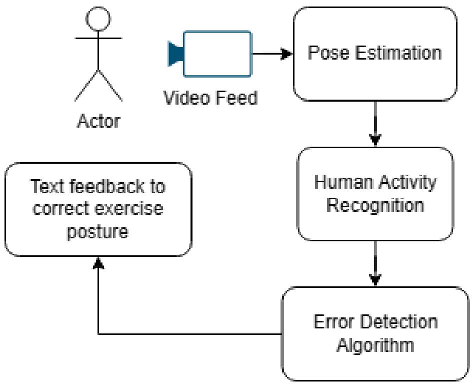

Fig. 1. Posture Correction System Overview

In Fig. 1, this shows the process of the system, the system is composed of a device with a camera and a software. The software contains deep learning models and an algorithm used for error detection in the posture.

II. METHODOLOGY

The methods used to create the system are grouped into deep learning models, error detection algorithm and software design.

A. Pose Estimation Model

The dataset was acquired in the MPII Human Pose Dataset, a rich resource containing images annotated with 16 key body joint locations. The dataset is then split into training, validation, and testing sets to facilitate model development and evaluation.

Next, we preprocess the dataset by standardizing image sizes to a consistent resolution suitable for input to the ResNet-50 model, typically 256x256 pixels. We normalize pixel values to the range [0, 1] and apply data augmentation techniques like random rotations, flips, and translations to enhance dataset variability and model generalization.

Fig. 2. Output of the Pose Estimation Model

In the fig. 2 we can see the example of output of the pose estimation model, from this we selected the joints as the pixels with red color.

B. Human Activity Recognition Model

In the Human Activity Recognition, we utilize a dataset derived from the pose estimation model, comprising key points representing body joint positions, and classify it into binary categories corresponding to activities like push-ups, lunges, and squats. This dataset is then divided into training, validation, and testing subsets for model training and validtation.

The key points extracted from the pose estimation serve as input features for the fully connected neural network architecture designed for binary classification. With the input nodes determined by the dimensionality of the key points, hidden layers incorporating suitable activation functions are added to capture intricate patterns within the data, culminating in an output layer equipped with a softmax activation function for generating binary classification predictions.

The model undergoes training on the training dataset, facilitated by backpropagation and gradient descent optimization, while monitoring via metrics such as loss, accuracy validation loss and validation accuracy on the training and validation set. Technique like dropout is applied to prevent overfitting and enhance generalization performance.

Upon completion of training, the model's efficacy is evaluated on the test set, employing metrics such as accuracy, and ROC curve.

C. Error Detection Algorithm

In the Error Detection algorithm, we used a combination of key points for each poses, we determined that at every pose there are only certain parts of the body that needed to be corrected.

TABLE I. IMPORTANT ANGLES

Exercise Classes	***Angles***
Squat	Torso, Legs
Lunges	Left Leg, Right Leg
Planks	Legs, Arms

Fig. 3. Important angles for each exercise classes.

In the fig. 3 we can see the key angles that we need to monitor in each exercises. For the squat, we monitor the angles in the torso and the legs of the user. For lunges, both the legs are monitored and for planks, we monitor the angle of the arms and legs.

```
public float CalculateAngle(Point p1, Point p2, Point p3)
{
    // Calculate vectors from p2 to p1 and p3
    Vector2 v1 = new Vector2(p1.x - p2.x, p1.y - p2.y);
    Vector2 v2 = new Vector2(p3.x - p2.x, p3.y - p2.y);

    // Calculate dot product and magnitudes
    float dotProduct = Vector2.Dot(v1, v2);
    float magnitudeV1 = v1.magnitude;
    float magnitudeV2 = v2.magnitude;

    // Calculate angle in radians using the dot product formula
    float cosTheta = dotProduct / (magnitudeV1 * magnitudeV2);
    float angleRadians = Mathf.Acos(cosTheta);

    // Convert angle to degrees
    float angleDegrees = angleRadians * Mathf.Rad2Deg;

    return angleDegrees;
}
```

Fig. 4. Code used in calculating angle.

In the fig. 4 we can see how the angle of the three points is calculated. We first calculated the two vectors of the angle based on point 1 and point 2, then point 2 and point 3. Next we performed dot product in both vectors, and calculated both magnitude of the vectors. Using the dot product and magnitude of the vectors, we can get the cosine of the angle, and finally we can use inverse cosine function to get the angle theta.

D. Software Design

Our software was created using Unity, the UI shows example images of the exercise. Our models were created using Keras and were converted using into Open Neural Network Exchange (ONNX) model to be imported into Unity.

Fig. 5. Important angles for each exercise classes.

In Fig. 5 we can see the UI of the software, on the left side of the UI, we have the predict and change sample buttons used for testing. We also have checkboxes for configurations and to enable the camera. On the right side we have the different classes with corresponding images.

III. TESTING AND RESULTS

The testing was conducted by using sample images and using camera, we split the data into testing and training data for the validation of the model.

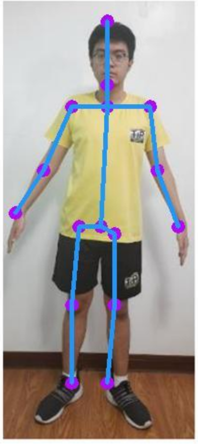

Fig. 6. Sample Output of Pose Estimation Model

The fig. 6 shows the example output of the pose estimation model, the calculation was stated in the methodology section.

TABLE II. ACCURACY/PRECISION SCORES

Body Parts	***Scores***
Head	96.351
Shoulder	95.329
Elbow	88.989
Wrist	83.176
Hip	88.420
Knee	83.960
Ankle	79.594

Fig. 7. Mean Average Precision for Pose Estimation Model

According to the Fig 7, most of the body parts scores shows greater than 75%. The model that we used shows a mean average precision (mAP) of 88.532 on the MPII dataset, it was the same dataset that it was trained on.

For our Human Activity Recognition model, we used accuracy and ROC curve for the evaluation of the model. Our model has achieved 99.17% accuracy during the training and 100% accuracy in the validation set.

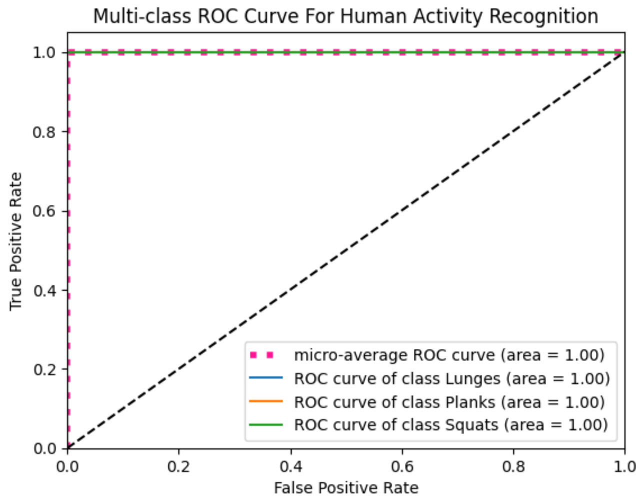

Fig. 8. Evaluation Metrics for Human Activity Recognition Model

In the Fig. 7, we can see the AUROC curve of the Human Activity Recognition model. This shows that the model can handle all the classes equally without any bias.

IV. CONCLUSIONS

After testing the system and changing some things for optimization purposes, we can conclude that this system can detect pose and classify it, the models showed great results all across the metrics. The pose estimation showed great performance in the device were we simulated the software. Furthermore, the error detection algorithm that we used worked as we expected, and the responses in the software was correct and consistent.

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