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Research Article

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Precision in Motion: AI for Workout form Optimization Using Joint Angles

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Abstract: Physical workouts and exercises are most effective when the associated body part(s) are in specific form. The form is also essential for the safety of the workout. The body can be prone to various injuries if the form is not correct while doing the workout. This paper covers a software solution that can be used to get the user in the correct form by adjusting the joint angles between the body part(s) for specific workouts. It uses computer vision and artificial intelligence libraries. The sample implementation is provided on GitHub GitHub - pythonioncoder/Fit-Form-AI.

Keywords: Pose Detection AI Libraries, Media pipe, AI Programming, Computer Vision, Artificial Intelligence, Fit Form AI

1. Introduction

Physical Workouts involve moving body parts from an initial form to a target form in order to exert pressure on the muscle group in and around a body part. Compound workouts involve more than one body part, sometimes a whole body. A few examples are pushups, pullups, and deadlifts. Isolation workouts involve single body parts, joints, or muscle groups. A few examples are bicep curls, stomach crunches, and knee raises.

One of the parameters of the correct body form is the angle around the joint of the target muscle group. For Example, while doing a Bicep Curl, an isolation workout, the arm should start from a fully stretched position having an angle of 160-180 degrees around the elbow joint and slowly transition towards the curl, making an angle of 30-45 degrees around the elbow joint. For doing a Squat workout, the body should move from an upright position to a sitting position, with a hip angle of 45-60 degrees and a knee angle of 90-120 degrees.

In recent times, software technologies for computer vision and artificial intelligence have become efficient and accurate. These can now detect and track the position and orientation of human body parts in images and videos. Using these libraries on images captured via the camera, the user can be guided from the initial body form to a target form.

Fig 1: *Starting and Finishing Form Angles for Bicep Curl Workout- An isolation Workout*

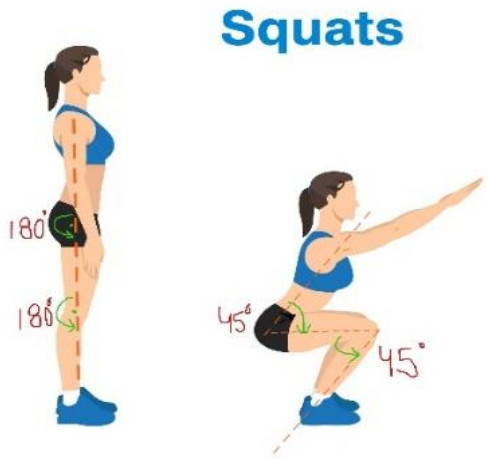

Fig. 2: *Starting and Finishing Form Angles for Squat Workout- A Compound Workout*

2. Human Pose Detection and Estimation

A. What

Pose detection and estimation is a feature of computer vision software that includes detection, association, and tracking of body parts' semantic points. For example, "right hand," "left shoulder," and "right knee." With the help of pose detection, computers can predict the poses of human body parts and joints.

B. Why and How

1) Technology

The performance of semantic point tracking in images and videos required high computational resources. With the advances in computer hardware and computational processing for AI, real-time image processing models are becoming economically and timewise feasible.

Various software libraries are available for pose detection-

1. OpenPose - OpenPose: Main Page (cmu-perceptual-computing-lab.github.io)
2. PoseDetection - Pose detection | ML Kit | Google for Developers
3. DensePose - DensePose
4. AlphaPose - GitHub - MVIG-SJTU/AlphaPose: Real-Time and Accurate Full-Body Multi-Person Pose Estimation&Tracking System
5. HRNet - HRNet · GitHub
6. MediaPipe Pose - Pose landmark detection guide | Google AI Edge | Google AI for Developers

Various pose libraries can estimate the human pose; Google AI library and media pipe pose landmark detection can be used to detect 33 key points. The key advantage of media pipe over other libraries is a rich set of output data points, efficiency, and accuracy. Media Pipe Pose is an ML solution for high-fidelity body pose detection, estimating 3D key points and background segmentation masks on the whole body from RGB video frames using BlazePose research.

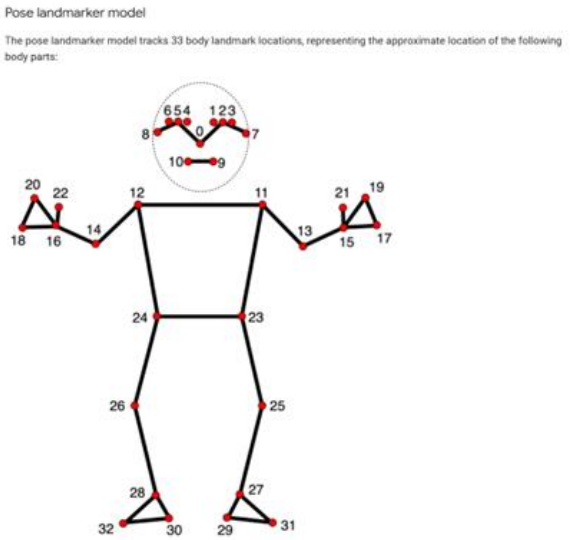

Fig. 3: *Key points detected via media pipe library.*

```
0 - nose
1 - left eye (inner)
2 - left eye
3 - left eye (outer)
4 - right eye (inner)
5 - right eye
6 - right eye (outer)
7 - left ear
8 - right ear
9 - mouth (left)
10 - mouth (right)
11 - left shoulder
12 - right shoulder
13 - left elbow
14 - right elbow
15 - left wrist
16 - right wrist
17 - left pinky
18 - right pinky
19 - left index
20 - right index
21 - left thumb
22 - right thumb
23 - left hip
24 - right hip
25 - left knee
26 - right knee
27 - left ankle
28 - right ankle
29 - left heel
30 - right heel
31 - left foot index
32 - right foot index
```

Fig. 4: *Key points detected via media pipe library.*

Convolutional Neural Networks (CNNs) are widely used in these software libraries. These libraries try to understand the geometric and motion information of the human body.

2) Solution Algorithm

The core algorithm of our software solution is to determine angles between various body parts using the output coordinates of the 33 key points mentioned above. These angles can be calculated using the distance formula and the Law of Cosines.

$$A = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$B = \sqrt{(x_2 - x_0)^2 + (y_2 - y_0)^2}$$

$$C = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2}$$

$$a = \cos^{-1}\left(\frac{A^2 - B^2 - C^2}{-2BC}\right)$$

Fig. 5: *Calculating angle between 3 points (x0,y0), (x1,y1) and (x2,y2)*

Using the calculated angles between the body parts, the user can be guided to an ideal body form for a selected workout.

C. Challenges

Because the human body's appearance can change due to various variables like clothing, viewing angle, and background, pose estimation has to be robust with real work variations. Bigger semantic points like arms, legs, neck, and head are relatively easy to detect and estimate, but smaller points like fingers and facial features can sometimes be difficult to detect and estimate.

The accuracy and effectiveness of our solution are directly proportional to the accuracy of the output data points given by the pose estimation library.

3. Futuristic View

Because the angles between the body parts are an important aspect of physical exercises and workouts, the solution can be extended to other physical activities, too. Examples are Posture correction and Yoga poses.

The solution is implemented in Python and can be executed on a computer with the Python ecosystem installed. The Future direction is to implement the solution on Mobile Operating Systems like iOS and Android so that the application can be accessed on Mobile Phones.

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