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Pose Estimation on Mobile in Strength Sports

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Abstract
In strength sports, where athletes require precise feedback on movement dynamics, equipment like linear encoders provides valuable data but lacks flexibility. Utilizing real-time multi-person pose estimation models, RTMDet and RTMPose, the proposed system captures detailed biomechanical data by tracking athletes' movements directly from video input, eliminating the need for direct equipment attachment to the athlete or barbell. This solution, implemented on a Python-based server architecture with an Android client interface, allows athletes to review their performance metrics such as mean propulsive velocity, providing insights into their technique and strength capacities. The application, validated against the high-precision Qualisys system, offers a portable alternative for athletes. This approach potentially extending its benefits to bodybuilders, strongmen, and other strength training disciplines.

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1. Introduction

Athletes need to know how they perform in their sport during training. For this purpose, endurance athletes use, for example, heart rate monitors. However, strength sports athletes must observe their movement dynamics, how fast they move a barbell for weightlifters and powerlifters, or a log or axle bar for strongmen.

Analyzing the velocity of a movement usually involves using hardware devices that need to be attached to barbells. The professional computer vision system should address issues such as impact of sampling rate, angle of view, camera shaking or other camera distortions, or how to convert video pixels to length units such as meters. The presentation layer must be simple and robust enough to handle rough conditions in dusty and sweaty gyms.

Existing solutions spreads from portable hardware devices, through solely mobile application up to complex multiple camera systems. Linear encoders along with accelerometers are widely adopted for their portability and sufficient simplicity of use. They are naturally dependent on postprocessing and data visualization which usually happens in companion mobile applications. The athlete needs to attach the devices to the barbell and then use the smartphone to analyze the measured data.

There exist commercial (publicly usable) camera systems, but they not portable and they are quite expensive (e.g. 3499$)n. On the other hand, they can also easily integrate a tablet or other touch screen and guide novice athletes during their exercise sessions.

For truly professional purposes, multiple camera systems such as Qualisys can be used. Qualisys provides extremely precise results, but requires laboratory style workflow and special procedures. This system can be calibrated at around 3mm error. The calibration must be done each measurement session, and usage of high reflexive points is required. The postprocessing has to be done per use case by a knowledgable person. Such system gives the best results, but is not publicly usable and costs tens of thousands dollars.

On the side of standalone mobile applications, there are very few options on Google Play. All of examined applications (e.g. WL Analysis, RepSpeed, Qwik VBT) require strict side view pointed to the weight plates. This suggest they use computer vision to track the round plate to measure the movement. This is not optimal, because when the athlete moves not symetrically, the system knows nothing about the other side of the barbell as it is not visible. The limited smartphone position forced by the application is not convenient for public gyms where the athlete cannot just place the phone everywhere.

Android application was developed to address the lack of a convenient solution for usage in public places. At the moment the solution uses a server-client architecture. Human pose computer vision model to estimate the athlete's movement runs at the server. Also exercise performance metrics are calculated there. In the Android application, users can play their videos and investigate velocity analysis along with insightful metrics such as mean propulsive velocity.

The proposed solution does not require the exercise to be recorded from any specific angle or position; even more, the weight plates could be completely out of view. The Android application is easy to use and offers intuitive interactions as user testing in the wild confirmed.

2. Server

The idea of using human pose estimation comes from the fact, that in strength sports, athletes hold the barbell in their hands. Tracking the wrists give us precise estimation of the barbell path and speed.

2.1 API

The server processing pipeline can be seen in Figure 1. The API is implemented using FastAPI library with the one main endpoint handling the request from Android application client. The request contains the video of the exercise along with data about the user such as height and gender. These values are used for proper calibration of the human pose estimaiton.

2.2 Human Pose Estimation

For estimating the athelte's pose and in the end the movement, RTMDet[1] and RTMPose[2] models are used. The architecture of the RTMPose can be also seen in Figure 1. The RTMPose uses SimCC approach. Instead of heatmap representation, SimCC treats keypoint localization as a classification task. The possible x an y axis of joints are quantized into discrete bins and then the keypoints are predicted based on these coordinations.

2.3 Performance metrics

Available metrics of exercise performance are mentioned in Section *Metrics*. The mean velocity and mean propulsive velocity describes what is the potential one repetition maximum. The metrics were chosen based on recent Gonalez sport study[3].

3. Android Application

The smartphone is already used by strength sports athletes to consult their technique and more with their coaches using video recordings. Caring about multiple devices in public gyms is pointing the attention from actual performance. For that reason, using standalone application for the whole analysis is convenient solution.

The Android application example view can be seen in Figure 2 showing the main screen in the app with recent analysis. The graph in the bottom part is a velocity of the movement, so athlete can investigate the movement in more detail. In the other tab, history of exercises is available. The user can replay the original video, display the velocity graph and see other details.

4. Evaluation

Evaluation sessions on multiple devices including multiple brands were performed. First evaluation was performed involving the Qualisys system mentioned in 1. In Figure 3 you can see the velocity graph of three repetitions (quite slow and controlled) of deadlift exercise. Followed by Figure 4 where you can see the absolute deviation from Qualisys measurement, which was taken as a ground truth. In the Figure 5 the Qualisys motion capture system the evaluation was perfomered can be seen.

5. Conclusions

The presented application offers a quantitative objective insight into the performance of strength sport athletes by providing velocity-based metrics such as visualization of the velocity of movement, mean and mean propulsive velocities and impulse. The scope of the usage covers typical strength sports such as weightlifting or powerlifting, but with minor extensions, it can be easily used by bodybuilders, calisthenics athletes, or strongmen. The solution does not require any specific positioning and the weight plates can be completely out of view.

Currently, the setup involves a Python server for the human pose estimation inference, but steps toward running this model inference on the edge were made. The calibration and conversion from pixels to metric units is crucial and several heuristics are integrated in the solution to achieve precise results. However, further calibration adjustments can push the product a the very first ranks in the industry.

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