# Exercise Form Analyzer

## Summary

The Exercise Form Analyzer is a computer vision application that utilizes MediaPipe's pose estimation features to provide real-time feedback about an individual's exercise form. The application offers single person and multi-person tracking, enabling detailed analysis of multiple different exercise movements such as bicep curls, deadlifts, squats, push-ups, and more. The application allows for video file processing and live webcam analysis with a user-friendly graphical user interface (GUI).

## Project Objectives

Robust Multi-person Tracking: Successfully implemented consistent ID tracking for up to multiple individuals.

Comprehensive Exercise Coverage: Performed analysis for 10 different exercise types with specific form requirements.

Real-time Exercise Form Analysis: Provided immediate feedback on exercise form quality during workout.

Data Export Capabilities: Enabled users to export analysis data for progress tracking and review

User-friendly Interface: Provided an intuitive GUI for easy interaction and visualization

Pose Smoothing: Implemented temporal smoothing to reduce noise in pose detection

## Essential Features

1. Multi-Person Pose Detection

- Simultaneous Tracking: Track multiple people at the same time
- Persistent ids: Use persistent IDs to track people from frame to frame leveraging advanced tracking approaches
- Color Coding: Each person is assigned different colors for tracking

2. Exercise Specific Analysis

- 10 exercise types: Bicep curl, deadlift, lateral raise, push-up, pull-up, back squat, Romanian deadlift, hammer curl, chest press, seated shoulder press
- Rule-based assessment: Each exercise has biomechanical rules and thresholds
- Multi-criteria assessment: Each exercise can have multi-criteria assessment with weighted importance of importance/weight

3.Real-time Feedback System

- on-screen overlays: Visual feedback with color coded count down

- Real-time scores: Live overall scores (0-1) with scores for individual components
- Textual Guidance: Feedback for specific changes in form

4. Data processing & export

- Time series storage: data will be collected for each frame of analysis
- Multiple export formats: data can be exported as JSON and CSV

5. Dual input mode

- Webcam Processing: Real-time analysis of video captured from camera feed
- Analysis of files: Ability to batch process video files of exercise

## Technical Stack

### Core Technologies

- **Python 3.x**: Primary programming language
- **MediaPipe**: Google's pose estimation framework for landmark detection
- **OpenCV (cv2)**: Computer vision operations and video processing
- **NumPy**: Numerical computations and array operations
- **SciPy**: Scientific computing, specifically spatial distance calculations

### GUI Framework

- **Tkinter**: Native Python GUI framework for cross-platform interface
- **PIL (Pillow)**: Image processing for GUI display integration

### Data Processing

- **Pandas**: Data manipulation and CSV export functionality
- **JSON**: Structured data storage and export
- **Collections (deque)**: Efficient data structures for temporal smoothing

**Detailed Logic Analysis**

File 1: MultiPersonExerciseFormAnalyzer (Main Engine)

- **Pose Detection**: Uses MediaPipe's pose estimation with model complexity 1 for balance between accuracy and performance
- **Smoothing Algorithm**: 5-frame moving average window to reduce detection noise
- **Memory Management**: Efficient data structures to prevent memory leaks during long sessions

**Key Methods**

- process_frame(): Core frame processing pipeline
- smooth_keypoints(): Temporal smoothing implementation
- calculate_angle(): Biomechanical angle computation
- save_analysis_data(): Data persistence functionality

File 2: FeedbackAnalyzer (Rules Engine)

**Analysis Logic**

- **Biomechanical Validation**: Each exercise evaluated against sport science principles
- **Multi-criteria Scoring**: Weighted combination of individual rule scores
- **Adaptive Thresholds**: Different tolerance levels for various movement patterns
- **Real-time Feedback Generation**: Immediate corrective suggestions

**Evaluation Metrics**

- **Angular Analysis**: Joint angle calculations using 3-point geometry
- **Stability Metrics**: Movement consistency and control evaluation
- **Alignment Checks**: Proper body positioning verification
- **Range of Motion**: Movement amplitude and execution quality

File 3: ExerciseAnalyzerUI (Interface Layer)

**GUI Architecture**

- **Modular Design**: Separate frames for different functional areas
- **Responsive Layout**: Adaptive interface that scales with content
- **Real-time Updates**: Threading for non-blocking video processing

- **Progress Tracking**: Visual indicators for analysis progress

**User Experience Features**

- **Exercise Selection**: Dropdown menu for exercise type selection
- **Input Source Toggle**: Radio buttons for webcam vs. video file selection
- **Live Feedback Display**: Real-time text feedback with color coding
- **Data Export Interface**: User-friendly export functionality

**Threading Implementation**

- **Main UI Thread**: Handles interface updates and user interactions
- **Processing Thread**: Manages video analysis without blocking UI
- **Callback System**: Efficient communication between threads

Challenges Faced & Solutions

1. Multi-Person Tracking Consistency.

Challenge: Maintaining consistent IDs for each person across rectangular frames when different people move or temporarily leave each rectangular frame.

Solution:

- Developed a PersonTracker class with distance matching.
- Used centroid tracking with configurable distance thresholds.
- Added a timeout for lost tracks at the frame level.

2. Real-time Performance Optimization.

Challenge: Maintain frame rate while doing complex pose analysis.

Solution:

- Decreased MediaPipe settings (model complexity=1).
- Used an efficient data structure to keep state (deque for smoothing).
- Reduced redundant work in analysis pipeline.

3. Pose Detection Noise.

Challenge: Jitter and noise in the raw pose landmarks caused motion analysis to be difficult.

Solution:

- Used 5-frame moving average smoothing.

- Made angle calculations more numerically stable.
- Used the property's vector norm to avoid division by zero errors.

4. Generalizing Exercise Rules.

Challenge: Create flexible rule sets that can be used for all variations of exercises.

Solution:

- Designed a weighted scoring system with user-configurable thresholds.
- Implemented modular rule definitions for easy extension.
- Added exercise-specific parameter validation.

Future Scope

This technology has the potential to greatly impact:

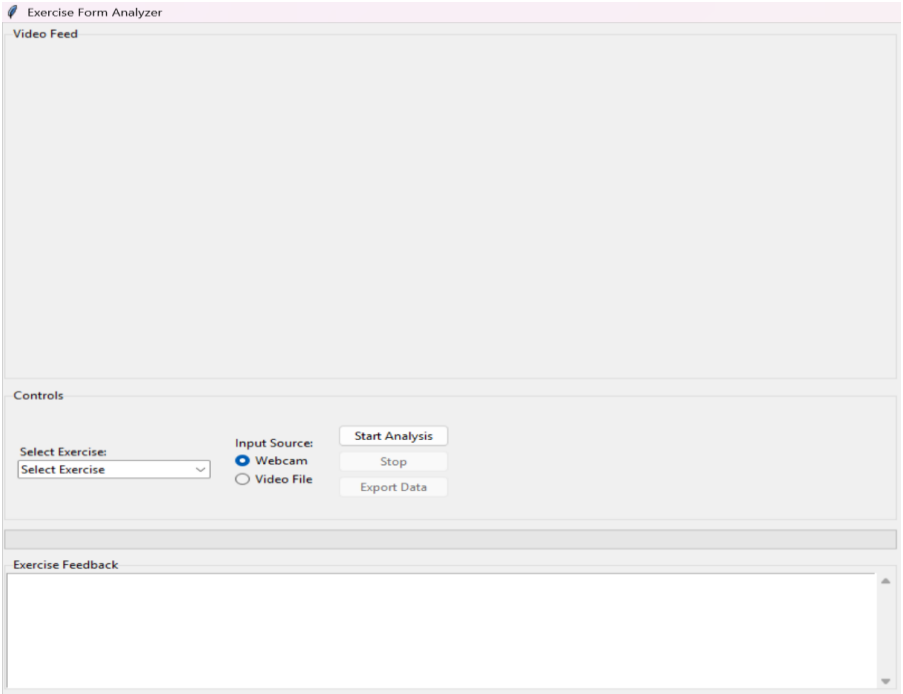
Injury Prevention: Preventing injuries due to improper workouts.

Accessibility in fitness: Providing access to professional form analysis to individuals in their homes.

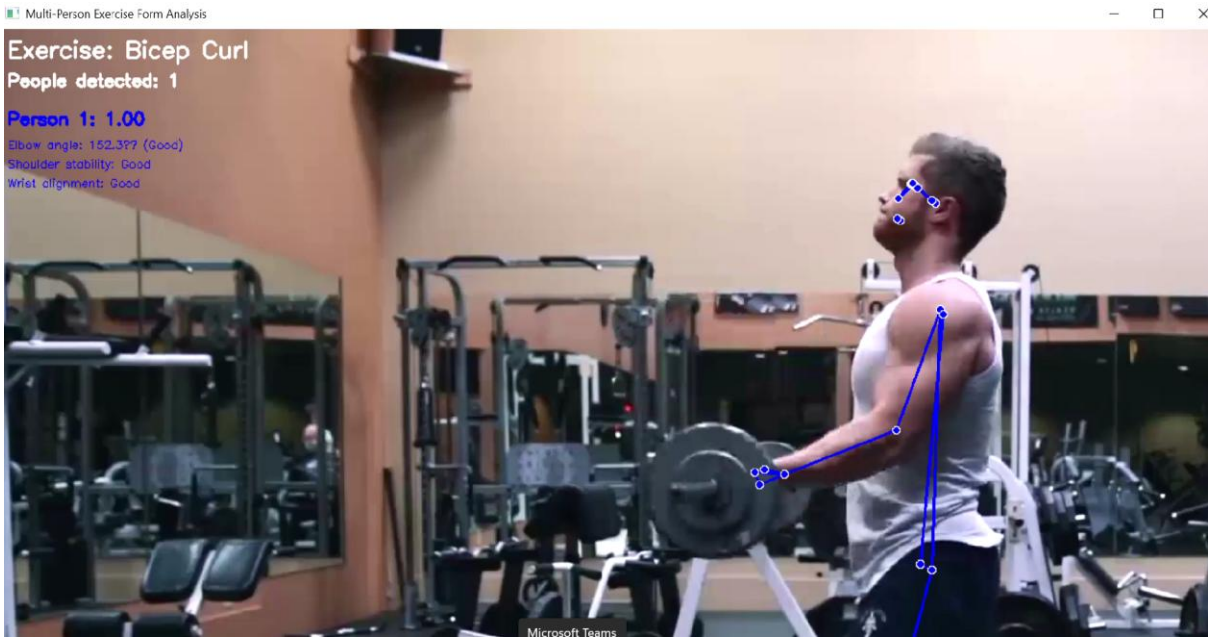
Increased training efficacy: Providing immediate feedback for an optimal workout.

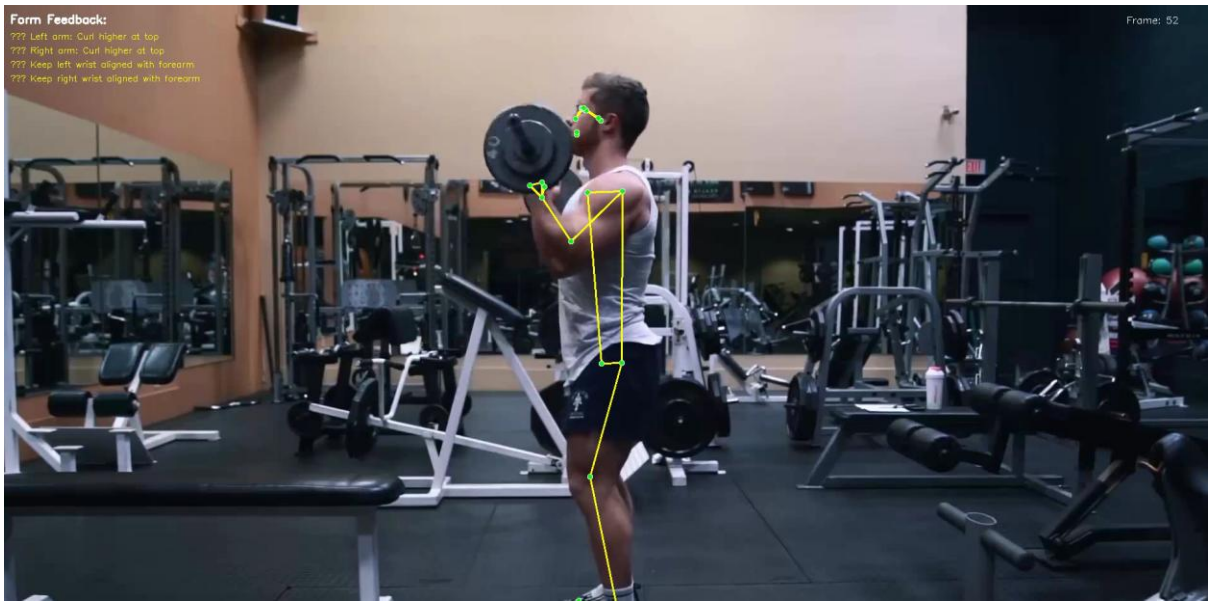
Results Screen shots

GUI




Prerecorded Video Analysis




## Feedback log

| frame_nur | stamp | person_id | overall_sc | feedback |
|---|---|---|---|---|
| 1 | 0.033367 | 0 | 0.48 | Back angle: 177.8Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 2 | 0.066733 | 0 | 0.48 | Back angle: 177.6Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 3 | 0.1001000 | 0 | 0.48 | Back angle: 177.3Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 4 | 0.1334666 | 0 | 0.48 | Back angle: 177.1Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 5 | 0.1668333 | 0 | 0.48 | Back angle: 177.1Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 6 | 0.2002000 | 0 | 0.48 | Back angle: 176.9Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 7 | 0.2335666 | 0 | 0.48 | Back angle: 176.1Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 8 | 0.2669333 | 0 | 0.48 | Back angle: 175.2Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 9 | 0.3003 | 0 | 0.48 | Back angle: 174.7Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 10 | 0.3336666 | 0 | 0.48 | Back angle: 173.9Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 11 | 0.3670333 | 0 | 0.48 | Back angle: 173.6Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 12 | 0.4004000 | 0 | 0.48 | Back angle: 174.0Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 13 | 0.4337666 | 0 | 0.48 | Back angle: 174.5Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 14 | 0.4671333 | 0 | 0.48 | Back angle: 175.3Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |
| 15 | 0.5005000 | 0 | 0.48 | Back angle: 176.1Â° (Adjust back position); knee_hip_sync: Monitoring; bar_path: Monitoring |

**The Posture Rule Used-**

| Exercise | Angle Rules | Symmetry Rules | Alignment/Posture Rules |
|---|---|---|---|
| **Bicep Curl** | Elbow angle (150° extend, 40° flex limit) | Hip symmetry | Elbows close to torso |
| **Deadlift** | Back angle > 165° | Knee alignment | Hips lower than knees |
| **Lateral Raise** | Arm raise ≥ 80° | Elbow height match | Upright torso |
| **Pushup** | Elbow bend ~90° | Straight body line (shoulder–heel) | No sagging or hip hiking |
| **Pull-up** | Elbow pulling angle < 60° (implied upward motion) | - | Avoid swinging, torso vertical |
| **Back Squat** | Knee angle < 90° | Hip alignment | Chest up, back straight |
| **Romanian Deadlift** | Hip hinge angle > 150° | - | Back straight, knees slightly bent |
| **Hammer Curl** | Elbow flex angle control (<40° excessive) | - | Wrist-neutral, elbows stable |
| **Chest Press** | Elbow depth to ~90° | - | Controlled descent, elbows out |
| **Shoulder Press** | Shoulder press angle > 150° | - | Press vertically, maintain spinal posture |

The exercise form evaluation rules developed for this project were based on a variety of guidelines that were primarily expert-driven guidelines for fitness, principles of biomechanics, and anatomy. The primary sources included guided material by trusted health and fitness organizations such as the American Council on Exercise (ACE), National Academy of Sports Medicine (NASM), and ExRx.net since these organizations provide non-negotiable descriptions of joint angle, body posture, and safe exercise performance.

Conclusion

The Exercise Form Analyzer combined computer vision, biomechanical analysis, and experience design. The project has accomplished execution from a technical perspective through its multi-person tracking, the range of exercises it can analyze, and a pleasant user experience.

References:


- https://www.acefitness.org/
- https://exrx.net/
- https://tfdgym.co.uk/
- https://pypi.org/project/mediapipe/
- https://ai.google.dev/edge/mediapipe/solutions/guide