Motion Tracking and Optical Flow for Tennis Swing Analysis

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Motivation

- Analyzing tennis swings is crucial for players to improve their technique, but detecting subtle differences between amateur and professional swings is challenging. Even with slow motion, measuring racket head speed throughout the swing—a key factor in generating maximum spin and ball speed—remains difficult.
- My goal is to solve this problem using optical flow and pose estimation to analyze swing paths and speeds, enabling players to understand and improve their technique.

New Technique

The computational imaging techniques that were utilized were MediaPipe for pose estimation and optical flow for motion tracking, to analyze and compare tennis swings between amateur and professional players. The method provides a detailed breakdown of swing paths and speeds, enabling players to identify areas for improvement. Unlike wearable sensors or basic 2D pose estimation, this approach can use normal speed video swings to measure the swing path and hand speed throughout the whole swing, providing quantitative and visual feedback.

Input Video
↓
Pose Estimation (MediaPipe)
↓
Wrist Tracking (Optical Flow)
↓
Speed Calculation
↓
Path Normalization
↓
Comparison (User vs. Pro)
↓
Output: Swing Paths, Speed Graphs, Metrics

Speed Calculation:

$$\text{speed\_px\_sec} = \sqrt{(\Delta x)^2 + (\Delta y)^2} \times \text{fps}$$

Path Normalization:

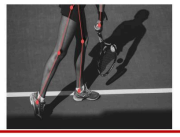
$$(x_{\text{norm}}, y_{\text{norm}}) = \left(\frac{x}{D_{\text{ref}}}, \frac{y}{D_{\text{ref}}}\right)$$

where:

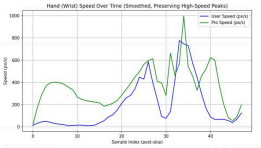
$$D_{\text{ref}} = \sqrt{(x_{\text{right}} - x_{\text{left}})^2 + (y_{\text{right}} - y_{\text{left}})^2}$$

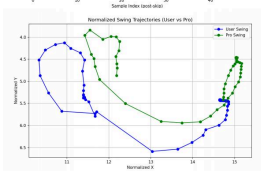
Related Work

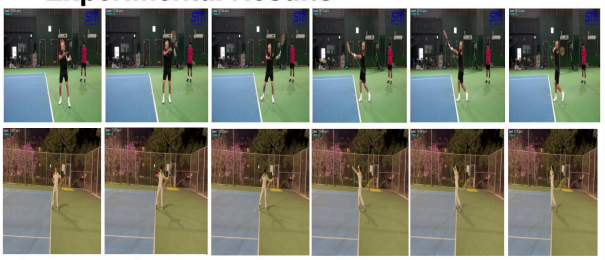
1. Wearable Sensors: Wearable sensors, such as accelerometers and gyroscopes, are attached to the player's body or racket to track motion and measure swing metrics.
2. Basic 2D Pose Estimation: detecting key body landmarks (e.g., wrists, elbows, shoulders) from video footage.
3. Real-time simulation involves creating a virtual representation of the player's motion using computer graphics.



Experimental Results







Metric	User	Pro
Mean Velocity (px/s)	193.70	363.31
Mean Acceleration (px/s²)	57.91	88.18
Net Distance & Angle		
Distance (px)	3.08	2.60
Angle (degrees)	167.07	167.92
Difference (User - Pro)		
Distance (px)	0.48	
Angle (degrees)	19.15	

References

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