Assumptions & Formulae

Pose Estimation Assumptions

- MediaPipe reliably detects key landmarks: shoulder, elbow, wrist, hip, knee, ankle, head, toe, heel
- Frame rate is consistent for velocity and smoothness calculations
- Wrist velocity spike corresponds to bat-ball contact

Biomechanical Calculations

- **Elbow Angle**: Angle between shoulder–elbow–wrist

  where BA = a - b, BC = c–b

$$\theta = \cos^{-1}\left(\frac{(BA \cdot BC)}{\|BA\| \cdot \|BC\|}\right)$$

- **Spine Lean**: Angle between hip–shoulder vector and vertical axis

$$\theta = \cos^{-1}\left(\frac{(\text{spine vector} \cdot [0, -1])}{\|\text{spine vector}\|}\right)$$

- **Foot Direction**: Angle between heel–toe vector and horizontal axis

$$\theta = \cos^{-1}\left(\frac{(\text{foot vector} \cdot [1, 0])}{\|\text{foot vector}\|}\right)$$

- **Head-Knee Alignment**: Horizontal distance between head and front knee

$$\text{Alignment} = |x_{\text{head}} - x_{\text{knee}}|$$

- **Wrist Velocity**: Euclidean distance between wrist positions across frames

$$v_i = \|\text{wrist}_i - \text{wrist}_{i-1}\|$$

Phase Segmentation Heuristics

- **Stance**: Minimal movement, low wrist velocity, stable elbow/spine
- **Stride**: Spine lean increases, elbow angle stable
- **Downswing**: Elbow angle increases, wrist velocity rises
- **Impact**: Wrist velocity ≥ 30
- **Follow-through**: Wrist velocity drops, elbow stabilizes