RefVision: CV assisted judging for powerlifting

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Agenda

1. **Introduction**
2. **Problem Statement**
3. **Proposed Solution**
4. **Deep Dive into Serverless Components**
5. **Architecture Walkthrough**
6. **Challenges and Solutions**
7. **Future Enhancements & Roadmap**
8. **Q&A**

1. Introduction & Story

Context

- Video Assistant Referees (VAR) are common in sports like football and tennis.
- Powerlifting faces frequent disputes over “No Lift” decisions, but lacks an appeal system.

Short Story

- A lifter’s squat gets turned down by judges. The lifter disagrees, losing a record attempt and $20k prize money—no recourse, no replay system.

Goal

- Leverage serverless AWS components to orchestrate a computer vision and natural language processing system for impartial video analysis and real-time feedback.

A Real-World Example

 <video width="800" height="450" controls> <source src="Keeta_squat_1.mp4" type="video/mp4"> Your browser does not support the video tag. </video>

2. Problem Statement

- **Contentious Calls**: Disagreements on squat depth or other reasons for failing a lift.
- **No Appeals Mechanism**: Lifters have no mechanism to challenge a decision.
- **Rising Stakes**: large and growing prize money and records magnify the importance of disputes.
- **Sport Integrity**: Unresolved and unexplained controversies diminish trust and viewer engagement.
- **Engagement**: experience from other sports show that the strategic introduction of VAR improves viewer engagement.

3. Proposed Solution: RefVision Virtual Referee

Key Concepts

1. **Supplement, Not Replace**: Works with referees, providing an objective second opinion.
2. **Appeal Mechanism**: One VAR appeal per meet encourages strategic usage without disrupting flow.
3. **Impartial Analysis**: Pose estimation + classification provide a quantitative and verifiable mechanism to judge “Good” vs. “No Lift.”
4. **Engagement**: Live overlays and natural-language explanations for the audience to understand the reasons for a decision.

Basic Architecture

 <img src="refvision_quick_overview.png" width="800" height="556" alt="Process flow diagram">

Why Serverless? And the Main Challenges

Benefits

- **Cost Efficiency**: Pay ~$0 when idle; scale up for meet day.
- **Zero Maintenance**: No servers to patch or manage.
- **Elasticity**: Automatically handle spikes in traffic or # of lifts.

BUT

- **Accelerators Needed**: Real-time CV inference demands accelerators.
- **No Native Serverless accelerators**: AWS Bedrock does this for LLMs, but not for computer vision.
- **Compromise Solution**: SageMaker endpoints for accelerator tasks.

4. Deep Dive: Key Components

4.1: Ingention & Preprocessing

- **Kinesis + Firehose**: Streams and on-the-fly and transforms (e.g., to .MOV to .MP4).
- **S3**: Stores raw video.
- **DynamoDB**: Records critical data for each lift attempt and metadata.

5.2 DynamoDB

- Central “store of state” for each attempt:
  - Preprocessing status
  - Inference results
  - Explanation text
  - Timestamps, lifter info

Data Model

- **Partition Key**: `LifterID_LiftID`
- **Sort Key**: `datatype_timestamp`

Partition Key	Sort Key	Metadata
12345_Squat1	Video_20240216T123456	Preprocessed frame data
12345_Squat1	Inference_20240216T123456	Inference results
12345_Squat1	Decision_20240216T123456	“Good Lift” / “No Lift”
12345_Squat1	Explanation_20240216T123456	LLM explanation

5.3 AWS Step Functions: Orchestrator

- **Orchestrator**:
    i. Waits for preprocessed frames
    ii. Triggers inference
    iii. Collects results, triggers explanation
    iv. Updates final status in DynamoDB
- Built-in retries & parallelisation if needed

5.3 Inference (SageMaker)

1. **Inference (SageMaker)**
    - YOLO11 Pose run on accelerator.
    - Output: Keypoints (hip, knee) and classification.
    - Writes “Good Lift” or “No Lift” to DynamoDB.
2. Identify turnaround frame for squat depth analysis.
3. perform depth analysis on the turnaround frame.

5.4 Explanation Generation (Bedrock)

Explanation (Bedrock)

- Bedrock is a joy to work with.
- Lambda is invoked once inference is done.
- Passes keypoints + classification → LLM for a short explanation of decision.
- Example:

> The squat was a ‘No Lift’ because the hip was 2cm above knee depth at the bottom.”

4.6 Web App & Delivery (Flask + CloudFront)

- **Flask**
  - Serves a simple UI for judges & audience.
  - Pulls annotated video from S3.
  - Fetches classification + explanation from DynamoDB.
- **CloudFront**
  - Caches static media (annotated videos) for fast delivery.

5. Flow Diagram:

 <img src="refVision_flow_diagram.png" width="900" height="636" alt="Process flow diagram">

Output: Annotated video with skeleton overlay

 <video width="800" height="450" controls> <source src="theo_maddox_squat_2.mp4" type="video/mp4"> Your browser does not support the video tag. </video>

6. Challenges & Solutions

1. **Serverless Accelerator Gap**
    - **Solution**: SageMaker endpoints scale to near-zero usage/cost off-peak.
2. **Asynchronous Coordination**
    - **Solution**: Step Functions + DynamoDB to orchestrate and track statuses.
3. **Accuracy & Multi-Person Scenes**
    - **Solution**: Fine-tune YOLO or add a classifier for “who is the lifter?”
4. **Human Trust & Acceptance**
    - **Solution**: Position it as an assistive tool, not a referee replacement.

7. Future Technical Improvements

1. **Multi-Camera Integration**
    - Emulate the three judges' perspectives simultaneously.
2. **Fine tuning Models**
    - Distinguish the lifter from handlers, audience, or background clutter.
    - capture the more nuanced rules of powerlifting
3. **Broader Sports & Markets**
    - Expand to Olympic weightlifting (snatch, clean & jerk).
    - Exercise physiology and rehabilitation
4. **RefVision as a Service**
    - Subscription-based API for other sports or rehab contexts.

Business Model

- Licensing RefVision to powerlifting federations.
- Offering an on-demand API service for coaches & lifters.
- Expand into other sports (Olympic weightlifting).
- Expand into exercise physiology and rehabilitation.

Q&A

If you're interested, please check out the code on GitHub:

 <img src="refvision_qrcode.png" width="400" height="400" alt="Process flow diagram">

Thank You!

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