Badminton AI Analysis: LangGraph Orchestration Pipeline

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What is Agentic AI?

- **Traditional ML/AI Systems (e.g., CNNs, Vision Transformers, LLMs):**
  - **CNNs (Convolutional Neural Networks):** Excellent for image classification, object detection. Primarily pattern recognition.
  - **Vision Transformers (ViTs):** Leverage self-attention for image tasks, capturing global dependencies. Still largely reactive.
  - **LLMs (Large Language Models):** Powerful for text generation, understanding. Can exhibit emergent reasoning but lack inherent agency or persistent state.
  - **Common Characteristics:**
    - *Monolithic & Reactive:* Designed for specific tasks, respond to input without internal goals or long-term planning.
    - *Limited Self-Correction:* Require retraining for significant behavioral changes.
    - *No Persistent State:* Each interaction is often independent, lacking memory across sessions.

Agentic AI Systems

- **Composed of autonomous agents with specific roles.**
- Possess capabilities such as:
  - Planning
  - Memory
  - Tool use
  - Self-reflection
- Can break down complex tasks, orchestrate actions, and adapt to new information.
- Aim for more human-like problem-solving, decision-making, and continuous learning.
- **Key Capabilities:** Planning, memory, tool use, self-reflection, and dynamic adaptation.
- **Examples:** Autonomous research agents, complex task automation systems, adaptive control systems.

LangGraph Pipeline for Badminton Analysis (1/2)

- **Multimodal Data Integration:**
  - Effective integration of video analysis (pose metrics) and audio transcription in a unified pipeline.
  - Sequential processing with comprehensive error handling for reliable results.
- **LangGraph for Sports Analysis:**
  - Pioneering the use of LangGraph for structured pipeline orchestration in sports analytics.
  - Foundation for future expansion to more complex agent interactions and workflows.
- **Actionable, Granular Feedback:**
  - Focus on generating highly specific, actionable feedback for players and coaches.
  - Moves beyond descriptive statistics to prescriptive recommendations.
- **Scalable & Extensible Architecture:**
  - Modular pipeline design allows for easy addition of new analysis capabilities in future iterations.

LangGraph Pipeline for Badminton Analysis (2/2)

- **Holistic System View:**
  - Our system seamlessly combines video (player movement) and audio (speech transcription) for comprehensive understanding.
- **Linear Pipeline Orchestration:**
  - Utilizes a four-node LangGraph pipeline for video processing, audio processing, and report generation.
  - Sequential processing with state management for efficient data flow between components.
- **Automated, Granular Reporting:**
  - Generates detailed, objective reports with actionable insights.
  - Identifies strengths and areas for improvement to support targeted coaching decisions.

How It Works: High-Level Overview

Input:

- Badminton match video.

Processing:

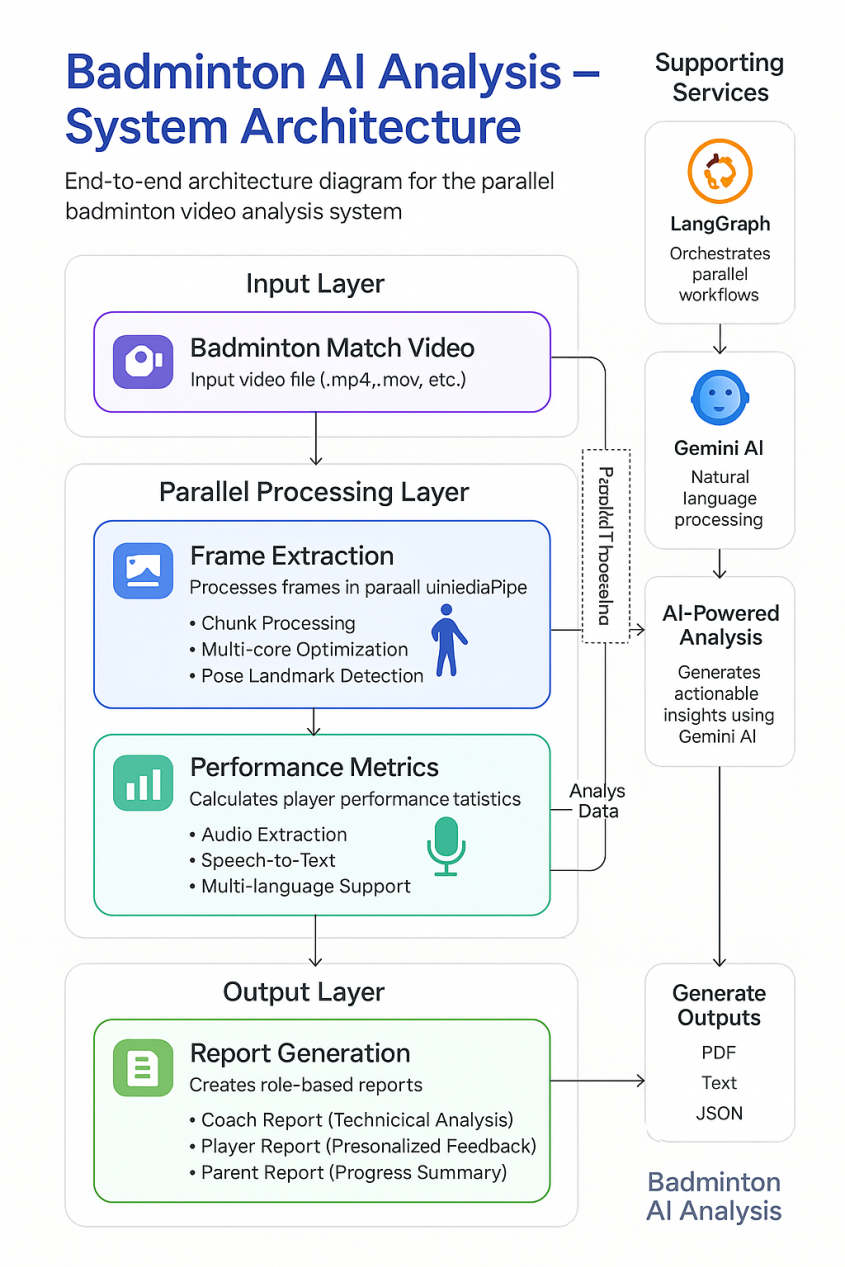
- Video frames are processed for pose estimation and audio is transcribed for speech content.
- LangGraph orchestrates a linear pipeline with four processing nodes for efficient data flow.

Output:

- Comprehensive text and PDF reports with actionable insights and strategic recommendations.

System Pipeline Overview

System Architecture Diagram



System Pipeline: High-Level Walkthrough (1/2)

- **1. Video Input:**
  - Raw match footage (e.g., MP4 files).
  - Supported formats: MP4, AVI, MOV with H.264/H.265 encoding.
  - Optimal resolution: 1080p (1920×1080) at 60fps for detailed motion capture.
- **2. Frame & Audio Extraction:**
  - Video is processed to extract individual frames for visual analysis.
  - Audio track is separated and processed for speech transcription.
  - Preprocessing includes frame resizing and color conversion.

System Pipeline: High-Level Walkthrough (2/2)

- **3. Pipeline Orchestration with LangGraph:**
  - Extracted data flows through a four-node linear pipeline orchestrated by LangGraph.
  - Pipeline includes video processing, audio transcription, data integration, and report generation.
  - State management ensures efficient data flow between processing steps.
- **4. Report Generation:**
  - Consolidated data is processed by Google Gemini API to generate comprehensive text and PDF reports.
  - Reports include performance metrics, observations based on pose data, and actionable feedback.
  - Customizable templates based on user role (player, coach, analyst).

Detailed Technical Implementation

LangGraph Pipeline: Architecture and Integration

- **Pipeline Architecture:**
  - Linear processing pipeline with four main nodes:
    - Video processing
    - Audio processing
    - Data integration
    - Report generation
  - Simple Directed Acyclic Graph (DAG) with sequential flow and error-handling edges.
  - Supports both synchronous and asynchronous execution using `asyncio`.
- **Integration with Python Ecosystem:**
  - Integrates with `asyncio` for non-blocking execution.
  - Compatible with:
    - MediaPipe (vision)
    - Google Web Speech API (audio)
    - Gemini API (report generation)

Key Components: Vision and Audio Nodes

- **Video Processing Node:**
  - **Primary Function:** Analyzes video frames for player pose
  - **Technical Implementation:** MediaPipe Pose model for human pose detection and tracking.
  - **Key Capabilities:** Pose estimation, elbow angle calculation, wrist distance measurement.
  - **Output:** Structured JSON with timestamped keypoints and performance metrics.
- **Audio Processing Node:**
  - **Primary Function:** Extracts and transcribes speech from the video's audio track.
  - **Technical Implementation:** PyDub for audio extraction; Google Web Speech API for transcription.
  - **Key Capabilities:** Multi-language support, silence-based segmentation.
  - **Output:** Transcribed text of spoken content.

Report Generation: Technical Implementation

- **Data Aggregation:**
  - **Input Sources:** Combines pose metrics from video analysis and speech transcription from audio.
  - **Data Sampling:** Processes first 100 pose metrics to manage context size for LLM processing.
  - **JSON Formatting:** Structures data in standardized format for AI model consumption.
- **Natural Language Generation:**
  - **AI Model:** Google's Gemini 1.5 Flash model generates contextual, role-specific reports.
  - **Role-Based Prompting:** Custom system prompts tailored to coach, student, or parent perspectives.
  - **Personalization:** Adapts language, technical depth, and focus areas based on target audience.
- **Multilingual Support:**
  - **Language Options:** Reports available in multiple languages (English, Hindi, Tamil, Telugu, Kannada).

Novelty and Innovation

Multimodal Data Integration:

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- Sequential processing with comprehensive error handling for reliable results.

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Actionable, Granular Feedback:

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Scalable & Extensible Architecture:

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System Implementation: Technical Stack

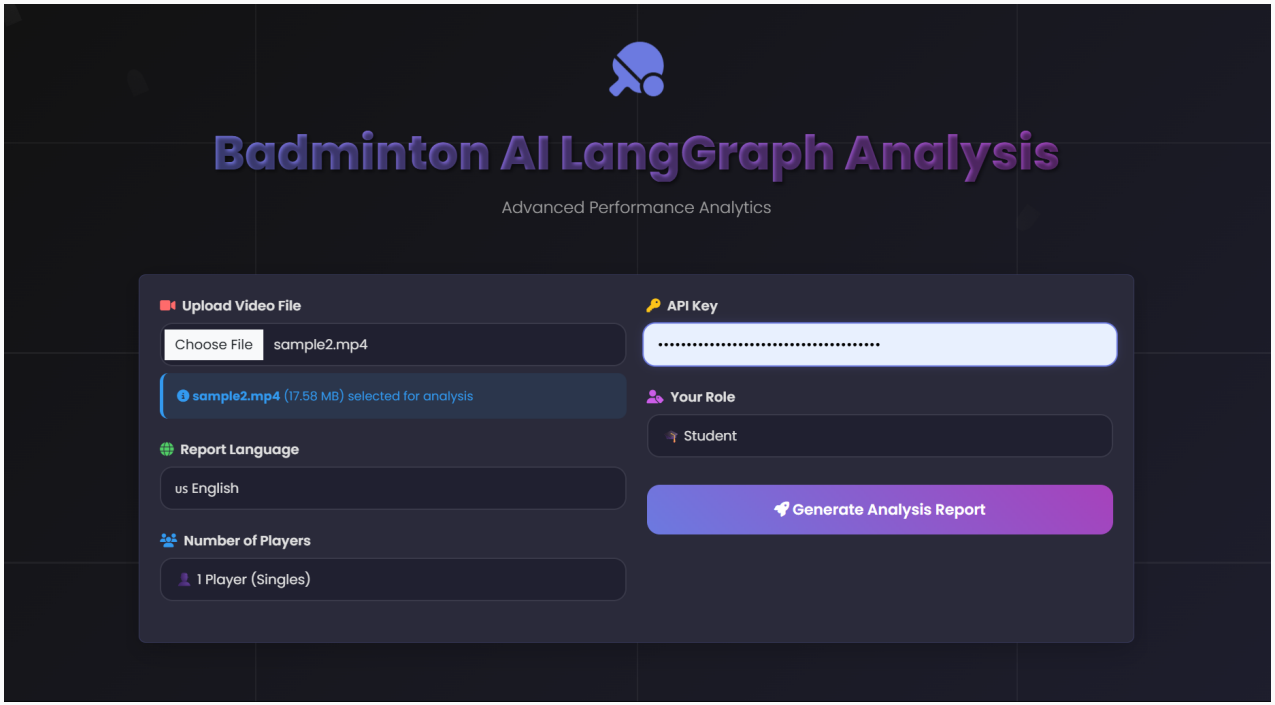
Frontend Technologies:

- **Web Interface:** HTML5, CSS3, JavaScript with responsive design.
- **Video Upload:** Custom file uploader with format validation and progress tracking.
- **Report Viewer:** Interactive PDF viewer with annotation capabilities.

Backend Technologies:

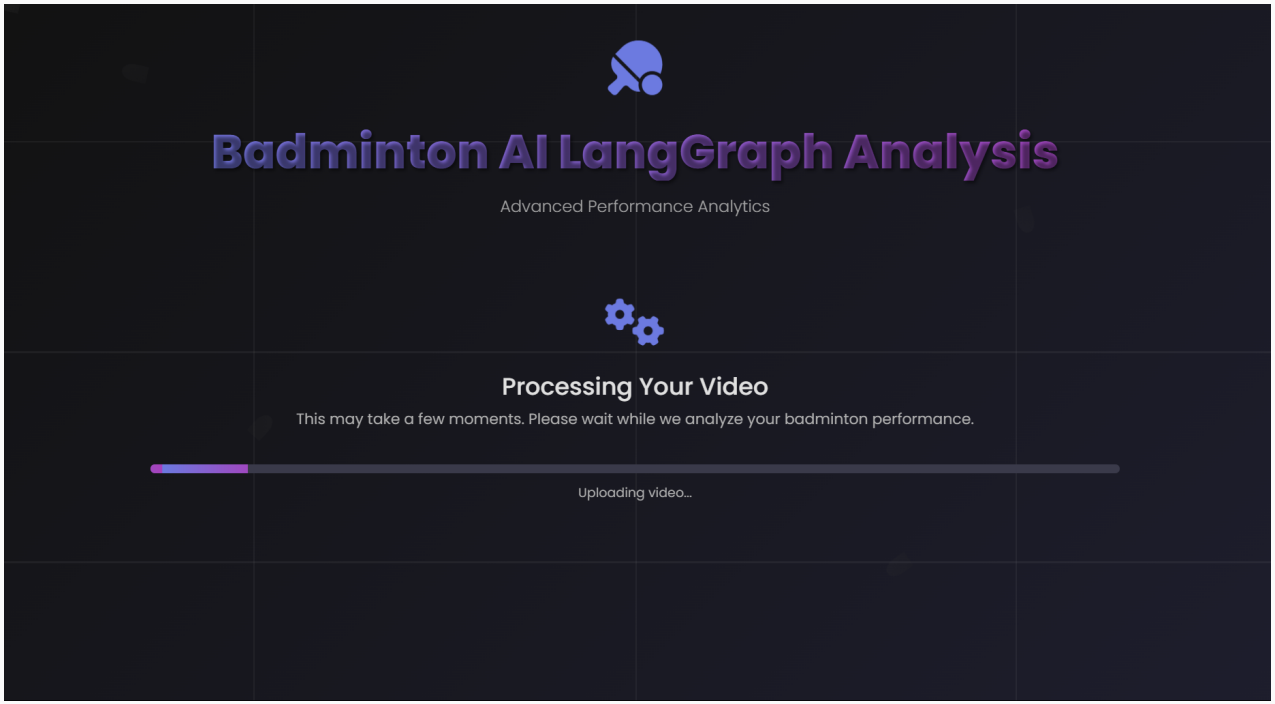
- **Server:** Flask for web application serving and file handling.
- **Video Processing:** OpenCV, MediaPipe for pose estimation and tracking.
- **Audio Processing:** Google Web Speech API for audio transcription.
- **Pipeline Orchestration:** LangGraph for linear pipeline definition and state management.
- **LLM Integration:** Google Gemini API for report generation with custom prompt templates.
- **Report Generation:** Custom templates for role-based and multilingual reports.

Demo Step 1: Upload Video



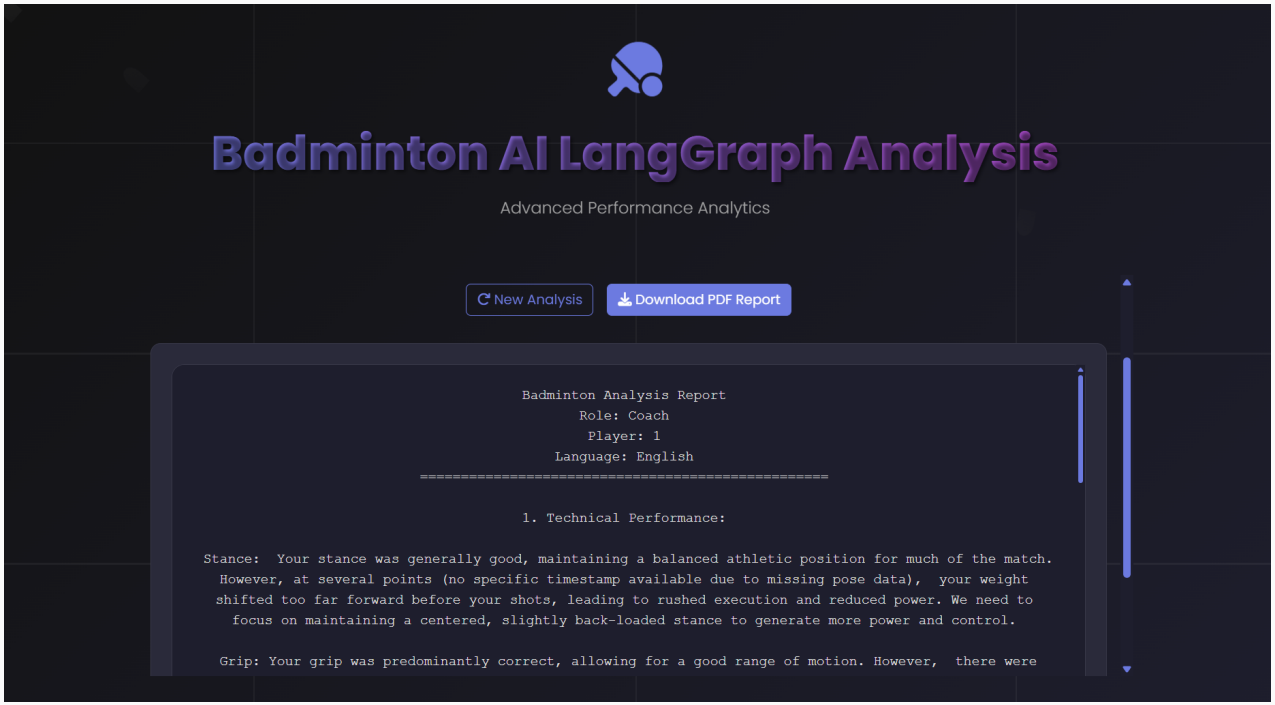
- User uploads a badminton match video and all necessary through the web interface.
- Supported formats include MP4, AVI, MOV.
- The system initiates pre-processing after recieving all information

Demo Step 2: Processing Status



- System displays processing stages with real-time progress indicators.
- Separate modules handle video frame extraction, pose detection, and audio transcription.
- Users are informed of each module's completion status.

Demo Step 3: Interactive Report



- An interactive, browser-based report is generated after processing.
- Key metrics like elbow angles, wrist distances, and speech insights are displayed.
- Visual overlays and summaries make interpretation intuitive.

Demo Step 4: Download PDF Report

- Users can explore specific sections in detail through the interface.
- A downloadable PDF report summarizes key findings for offline review.
- Report layout adapts to role — coach, player, or parent.

Demo Walkthrough: User Experience Summary

- **Complete Journey Overview:**
  - **Step 1: Upload** — Upload badminton match video via a simple interface.
  - **Step 2: Process** — Monitor real-time progress with clear indicators.
  - **Step 3: Report View** — See insights in a rich, interactive web view.
  - **Step 4: Export** — Download professional reports for long-term use.
- **Focus on Usability:** Designed for non-technical users (coaches, athletes).
- **Future Enhancement:** Mobile-friendly UI and real-time streaming support.

Thank You!

Questions?

Demo Video

▶ Click here to watch on YouTube

GitHub Repository

Click here to view the code

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