

COURTMETRICS – UNLOCKING TENNIS INSIGHTS WITH MACHINE LEARNING

Team Members:

Gautham Gali

Ashutosh Reddy Pochamreddy

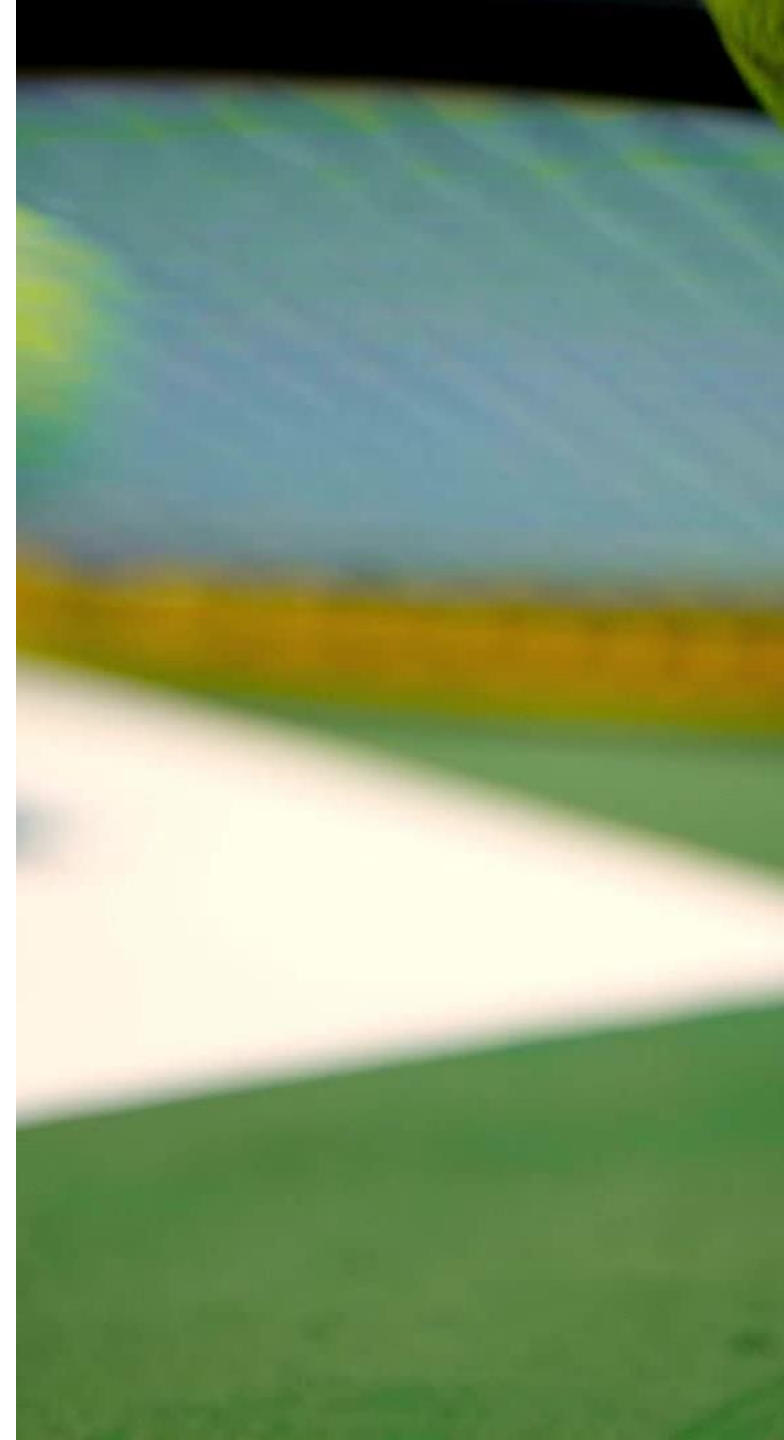
Atharva Rajendra Sardar

Lokesh Devendra Satpute

Professor. Soheil Sibdari

Overview

- **Objective:**
- Enhance tennis video analysis through deep learning-based detection of player actions, ball tracking, and court keypoints to provide comprehensive match insights.
- **Ball and Player Tracking:** Successfully integrated tracking mechanisms for both ball movement and player actions within match videos.
- **Court Keypoints Detection:** Developed a mini-court overlay for enhanced visualization.
- **Player Action Analysis:** Completed player action detection.
- **Player Statistics Analysis:** integrated player vs player statistical analysis using ATP data and Utilized Azure Openai Services.
- **Deployment & Optimization:** Deployed Our Services Using Azure VM and Azure OpenAI service.



Dataset

- Size:** 8,841 images (75% training, 25% validation)
- Resolution:** 1280 × 720
- Content:** Hard, clay, and grass courts
- Source:** Semi-automated extraction from YouTube highlights

Link:

https://drive.google.com/file/d/1hAaeQCmk2y440PmagA0KmIVBllysVMwu/view?usp=drive_link

Dataset

- **Tennis Player Actions Dataset for Human Pose Estimation**

- **Size:** 500 images each

- **Resolution:** 1280 × 720

- **Content:** The actions in this dataset, the action categories name in COCO-format is in brackets:

- 1. backhand shot (backhand)
- 2. forehand shot (forehand)
- 3. ready position (ready_position)
- 4. serve (serve)

We use COCO-Annotator to annotating and categorizing human actions

- ["nose", "left_eye", "right_eye", "left_ear", "right_ear", "left_shoulder", "right_shoulder", "left_elbow", "right_elbow", "left_wrist", "right_wrist", "left_hip", "right_hip", "left_knee", "right_knee", "left_ankle", "right_ankle", "neck"]

- **Source:** Mendeley Data

Link:

<https://data.mendeley.com/datasets/nv3rpsxhkh/1>

Tools

- FrontEnd: HTML, CSS, JS
- Backend: Flask, PostgresDB, python, Azure Open AI
- ML models: yolov8, Tracknet CNN, ResNet-18
- Azure Services: Azure Virtual Machine, Azure Open AI, Azure Virtual net, Azure DNS, Azure Resource groups, Azure public IP
- LLM: gpt-4o (version:2024-08-06)
- Visualization: seaborn, matplotlib
- IDE: Visual Studio Code, Azure OpenAI Service
- Other: Trello, kanban, Jira
- Communication: zoom, WhatsApp, slack

Sprint

The screenshot displays a Trello workspace named 'capstone-project' in a Kanban view. The workspace is organized into three columns: 'frontend', 'ML', and 'backend'. Each column contains several task cards with due dates. The 'frontend' column has five cards, 'ML' has five cards, and 'backend' has five cards. The interface includes a left sidebar with navigation options like 'Boards', 'Members', and 'Workspace settings'. The top of the board shows the workspace name, visibility settings, and the current board view.

Column	Task Name	Due Date
frontend	Youtube Downloader	Oct 8
	API Player Ranking	Oct 10
	API Matches Schedule	Oct 10
	Video Processing Environment	Nov 10
	Website integration ML, Stats and graphs	Dec 6
ML	Player Detection Models	Oct 16
	Player vs Player statistics	Nov 10
	Player Action Detection	Oct 23
	Player Statistics using Open AI model	Dec 6
	Get Player Overview, Career Highlights, Head-to-Head Records, Performance Statistics, Tournament History, Ranking Progression, Historical Trends using player names in match using GPT	Dec 6
backend	Server processing Videos	Oct 12
	API players ranking	Oct 12
	API Match schedule	Oct 12
	API News	Oct 12
	Create Azure AI service	Dec 6
Create Azure VM service	Dec 6	

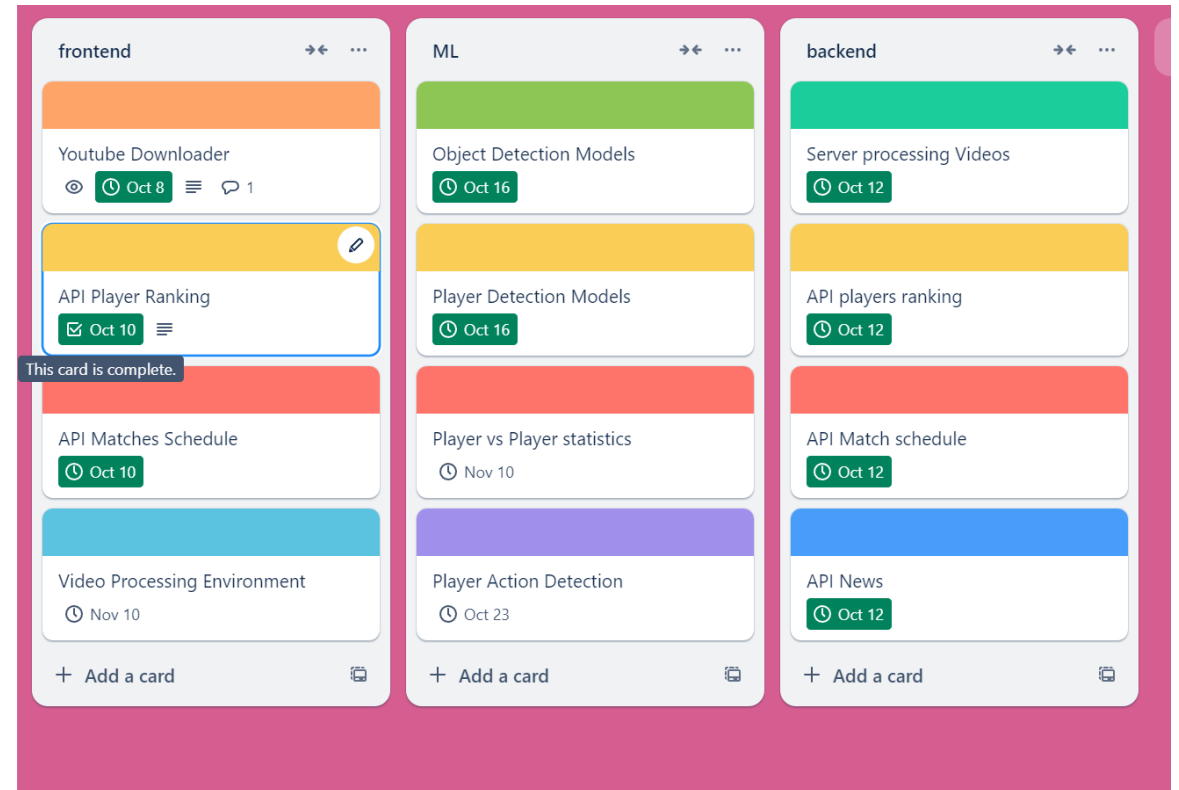
Sprint 1 Achievements

•Completed:

- Video download/upload feature
- Player ranking API and match scheduling API
- Backend server setup for video processing

•Ongoing:

- Player detection models and player vs. player statistics
- Video processing framework (Due: Nov 10)



Sprint 2 Achievements

•Completed:

- **Ball Tracker Integration:** Successful tracking and monitoring of ball movement during match videos.

- **Player Tracker Integration:** Accurate tracking of players within match videos for detailed analysis.

- **Court Keypoints Detection:** Mini-court overlay with key points for enhanced match visualization.

- **Player Action Detection:** Completed detection of key player movements.

- **Player vs Player Statistics Analysis:** Integrated ATP data for comprehensive player comparisons.

• Ongoing:

- Integrating everything

- Video processing framework (Due: Nov 20)

Task	Category	Priority	Assigned To	Status	Due Date
Integrate Ball Tracker	Machine Learning	High	ML Team	Completed	30-Oct
Develop and Integrate Player Tracker	Machine Learning	High	ML Team	Completed	30-Oct
Implement Court Keypoints Detection	Machine Learning	High	ML Team	Completed	31-Oct
Detect Player Actions	Machine Learning	High	ML Team	Completed	31-Oct
Player vs Player Statistics Analysis using ATP Data	Machine Learning	High	ML Team	Completed	3-Nov

Sprint 3 Achievements

•Completed:

- **Ball Tracker Integration:** Successful tracking and monitoring of ball movement during match videos.
- **Player Tracker Integration:** Accurate tracking of players within match videos for detailed analysis.
- **Court Keypoints Detection:** Mini-court overlay with key points for enhanced match visualization.
- **Player Action Detection:** Completed detection of key player movements.
- **Player vs Player Statistics Analysis:** Integrated ATP data for comprehensive player comparisons.
- **Integrated Azure VM and Deployment.**

Detailed Backlog Table

	Category	Task	Status	Assigned To	Due Date	
1	Frontend	YouTube Downloader	Completed on Oct 8	Gautham	Oct 8	
2	Frontend	API Player Ranking	Completed on Oct 10	Ashutosh	Oct 10	
3	Frontend	API Matches Schedule	Completed on Oct 10	Lokesh	Oct 10	
4	Frontend	Login and Signup Pages	Completed on Nov 25	Atharva	Nov 25	
5	Frontend	Video Processing Environment	Due Date: Nov 10	Lokesh	Nov 10	
6	Frontend	Frontend Dashboard Integration	Completed on Nov 27	Atharva	Nov 27	
7	Machine Learning (ML)	Object Detection Models	Completed on Oct 16	Ashutosh	Oct 16	
8	Machine Learning (ML)	Player Detection Models	Completed on Oct 16	Ashutosh	Oct 16	
9	Machine Learning (ML)	Player vs Player Statistics	Completed on Nov 10	Gautham	Nov 10	
10	Machine Learning (ML)	Player Action Detection	Completed on Oct 23	Ashutosh	Oct 23	
11	Machine Learning (ML)	Speed Calculations	Completed on Nov 26	Ashutosh	Nov 26	

SPRINT RETROSPECTIVE & NEXT STEPS

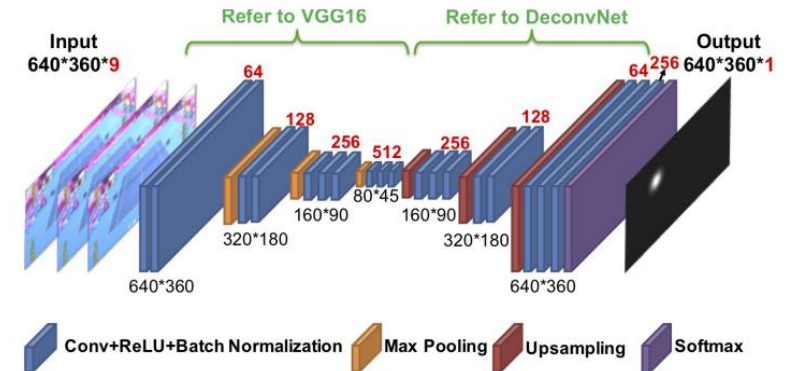
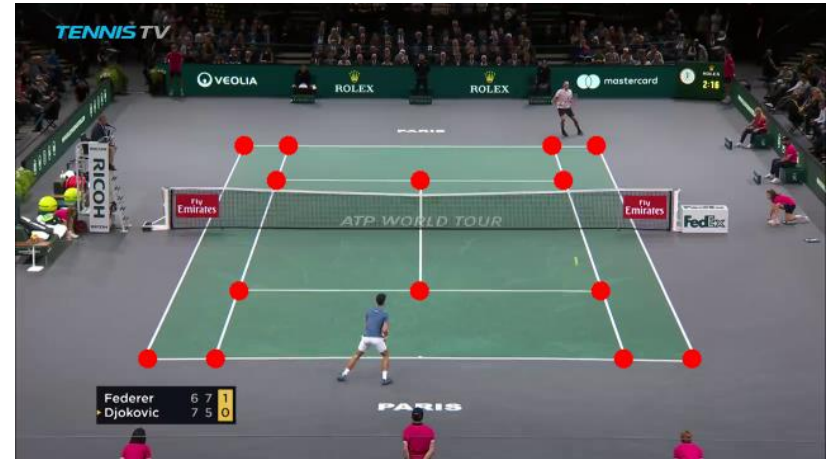
	A	B	C	D	E	F
1	User Story	Priority	Task (Summary)	Description	Total Time Estimated (hrs)	Status
2	Upload Match Video	High	Develop video upload API, file validation, and test video	Upload match video for analysis	13	Completed in Sprint 1
3	View Match Analysis	High	Design dashboard, integrate results, and conduct UI testing	View analysis on the match dashboard	18	Completed in Sprint 1
4	Ball Tracker Integration	High	Develop ball tracking ML model, optimize, and integrate data	Track ball movement, speed, and key moments	14	Completed in Sprint 2
5	Player Tracker Integration	High	Develop player tracking ML model, optimize, and visualize	Track players' positions, movements, and patterns	16	Completed in Sprint 2
6	Court Keypoints Detection	High	Detect court keypoints, overlay mini-court, and test accuracy	Overlay detected court keypoints for visualization	15	Completed in Sprint 2
7	Player Action Detection	High	Detect and label key player actions in matches with	Detect actions like serves, volleys, and smashes	18	Completed in Sprint 2
8	Player vs Player Statistics Analysis	High	Integrate ATP datasets, compare players, and display	Compare player statistics using ATP data	12	Completed in Sprint 2
9	Ensure Model Accuracy	High	Improve and validate ML models for accuracy and consistency	Ensure accurate detection of match events	18	Completed in Sprint 3
10	Finalize Player vs Player Comparison	Medium	Implement player comparison feature and conduct A/B testing	Enhance player comparison functionality	15	Completed in Sprint 3
11	Final Testing & Refinement	Medium	Perform system-wide testing, bug fixes, and final refinements	Refine system and prepare final output	19	Completed in Sprint 3
12	Azure VM Deployment	High	Deploy Flask app on Azure VM, configure DNS, and test access	Deploy the app to Azure VM for scalability	10	Completed in Sprint 3
13	Azure OpenAI Integration for Player Stats	High	Deploy GPT model on Azure OpenAI, retrieve stats, and	Integrate GPT to retrieve Player-vs-Player stats	12	Completed in Sprint 3



DEMO

Model Architecture

- **Tennis Court Detection Model:**
- TrackNet architecture Neural network
- Input: 1 image; Output: 15 channels (14 keypoints + court center)
- Input/Output resolution: 640×360



Model Architecture

- **Tennis Player and ball tracking:**
- YOLO (You Only Look Once): Real-time object detection system with high speed and accuracy.
- YOLOv8: Enhanced version with an anchor-free design and improved feature extraction.



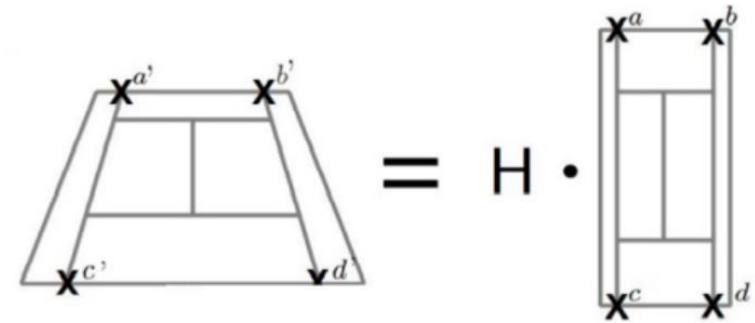
Post-Processing Techniques

- **Refining Keypoints:**

- Extract white pixels, detect lines, and use intersections to correct predictions.

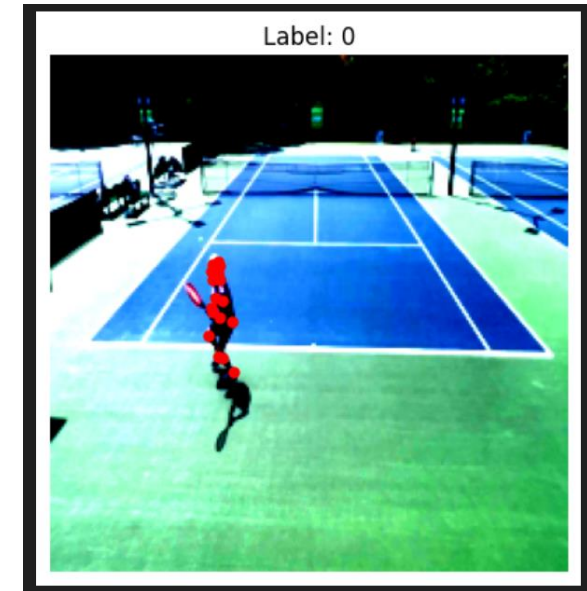
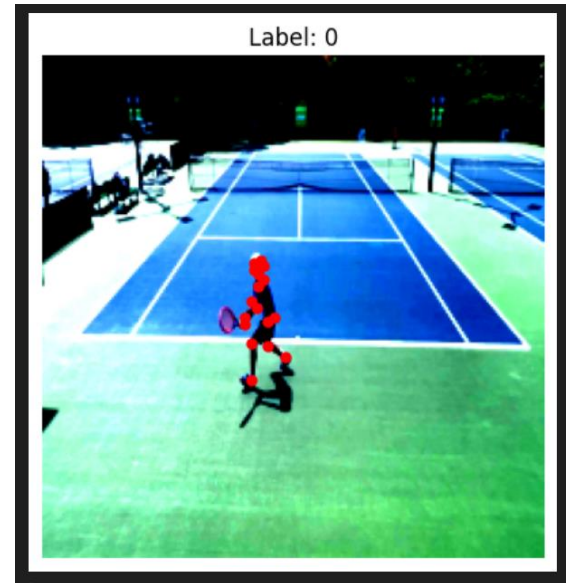
- **Homography Adjustment:**

- Apply homography matrix to compare and shift predicted keypoints for occluded areas.



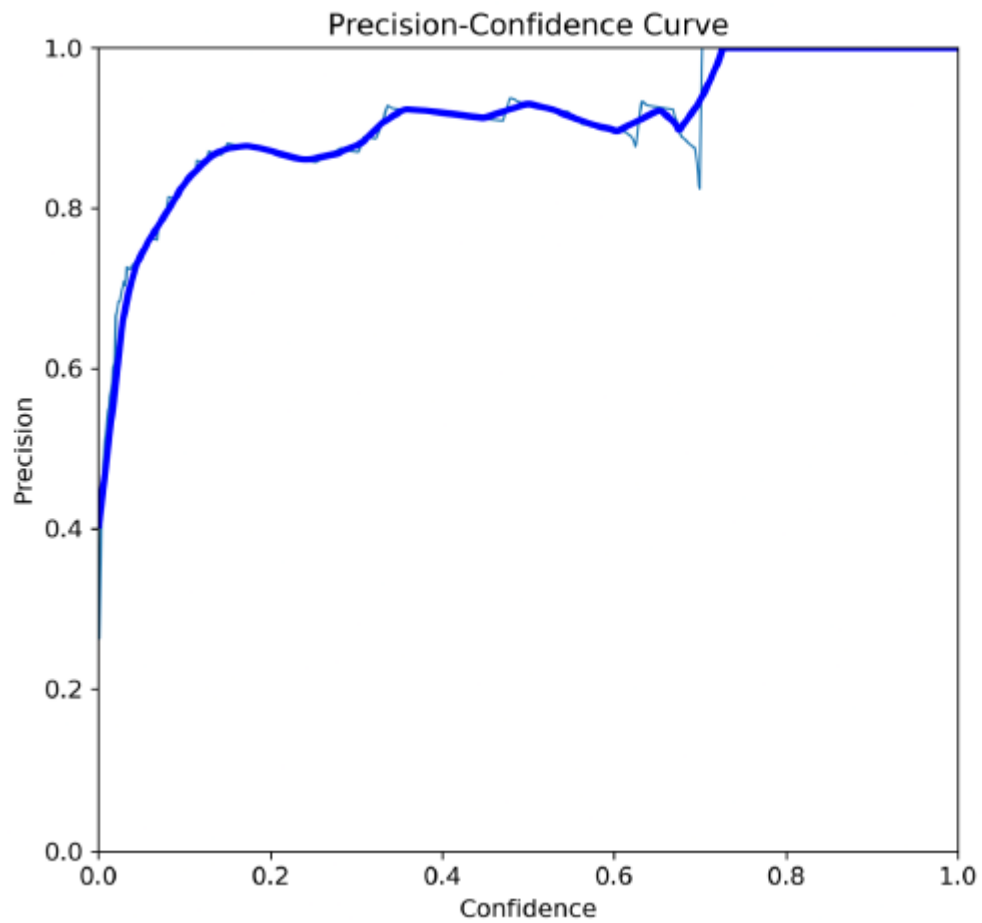
Model Architecture

- **Player Action Detection Model:**
- **ResNet-18 Backbone:** Pretrained ResNet-18 used for feature extraction with a modified output layer.
- **Custom Heads:**
- **Keypoint Head:** Predicts 18 (x, y) keypoints.
- **Classification Head:** Classifies actions (Backhand, Forehand, Ready Position, Serve).
- **Input-Output Flow:** Takes RGB images as input; outputs pose keypoints and action logits.

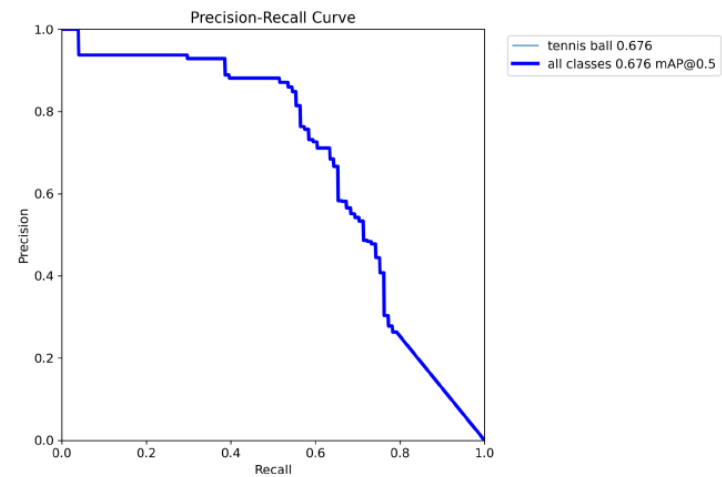


Model Results

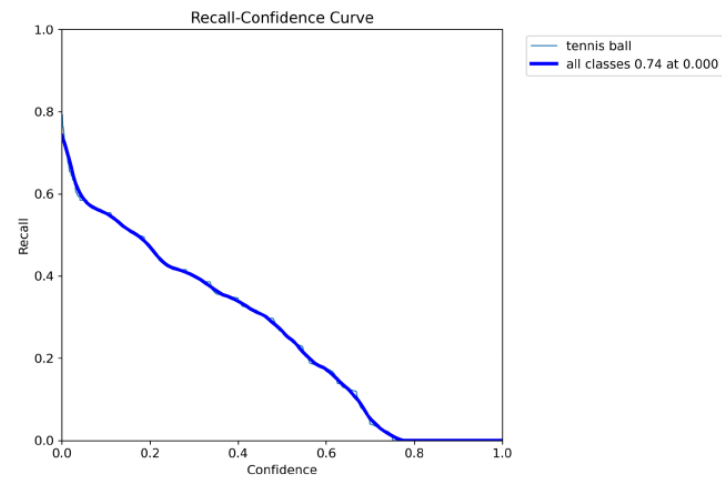
- Tennis Ball Detection Model:



tennis ball
all classes 1.00 at 0.728



tennis ball 0.676
all classes 0.676 mAP@0.5



tennis ball
all classes 0.74 at 0.000

Model Results

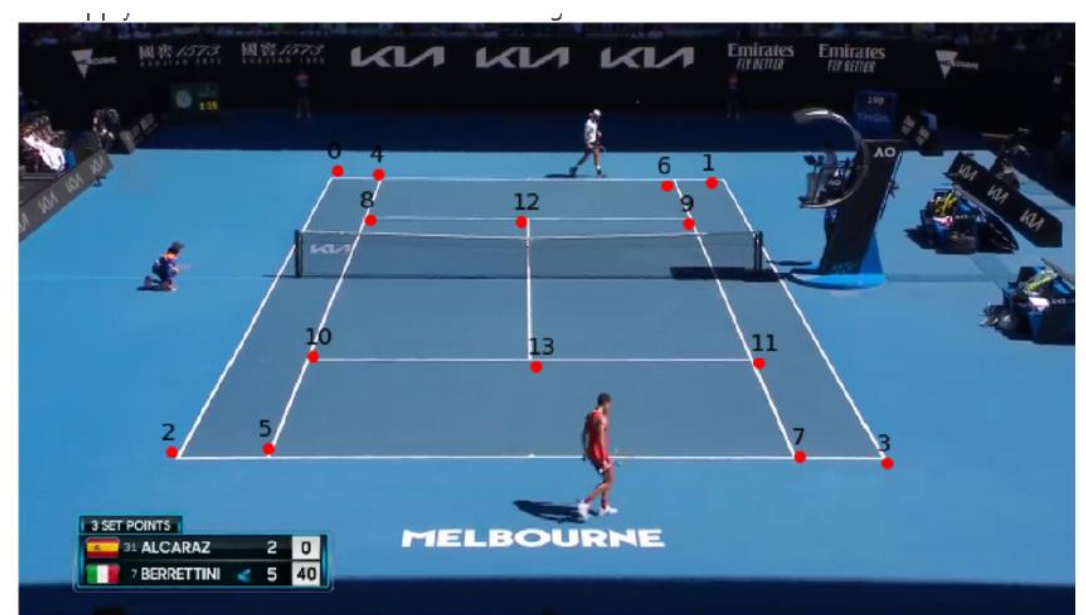
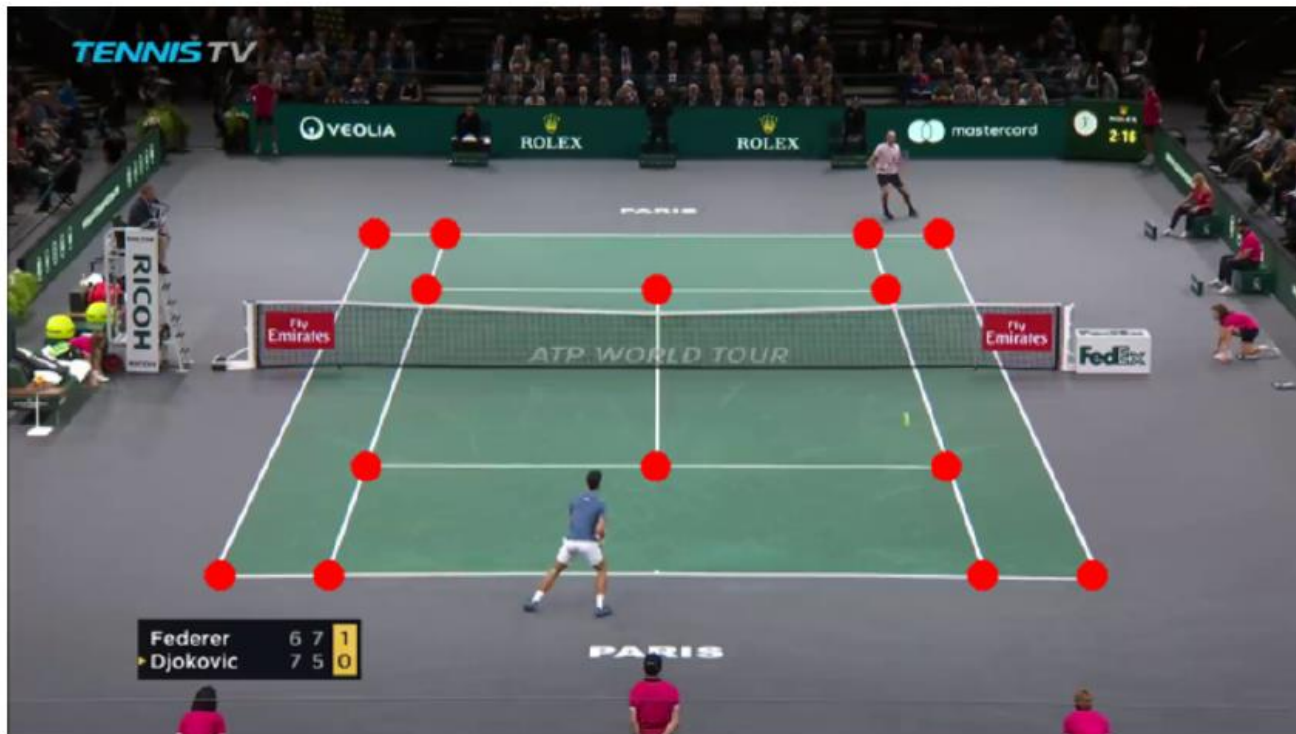
- Tennis Player Detection:



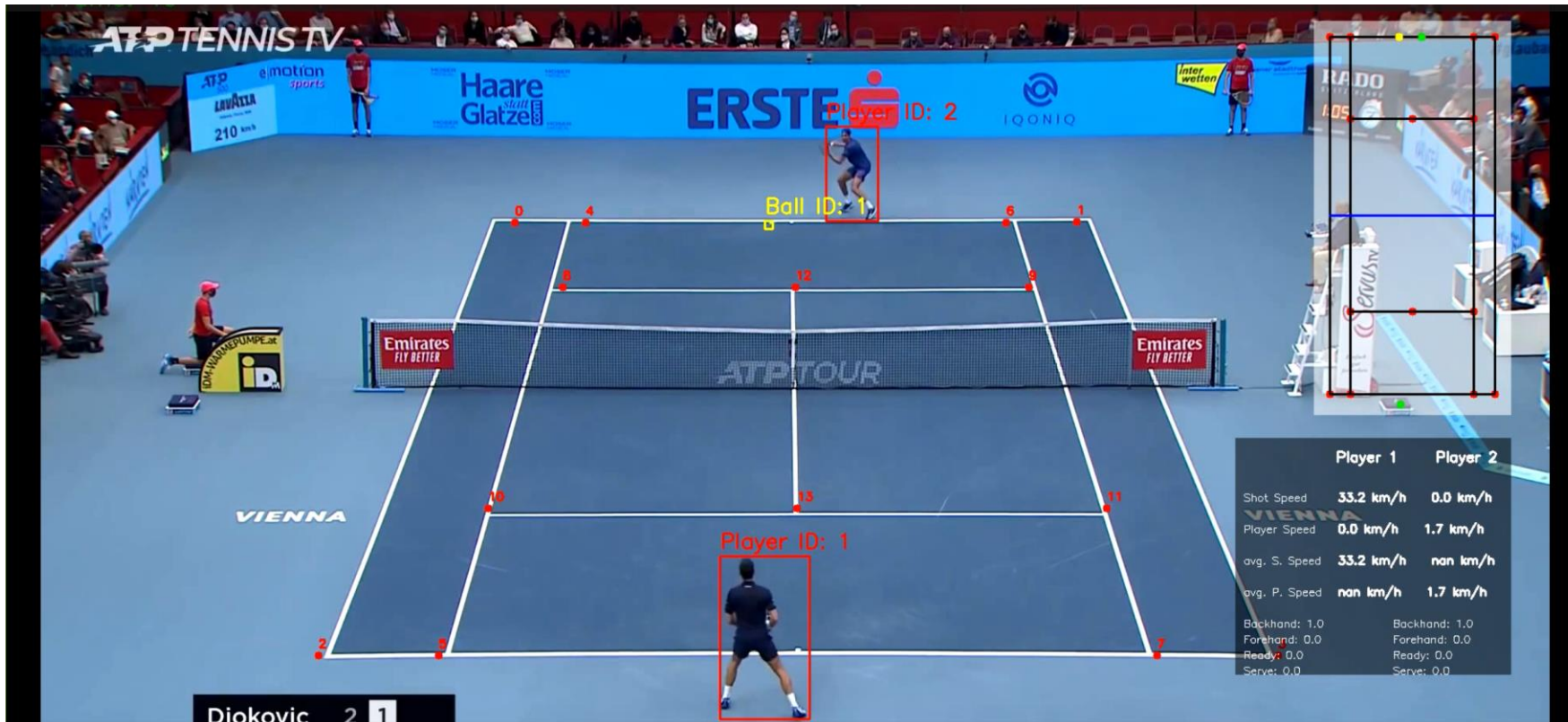
	Precision	Recall	f1
From article	95.5	75.7	84.3
My implementation	93.9	86.6	89.9

Model Results

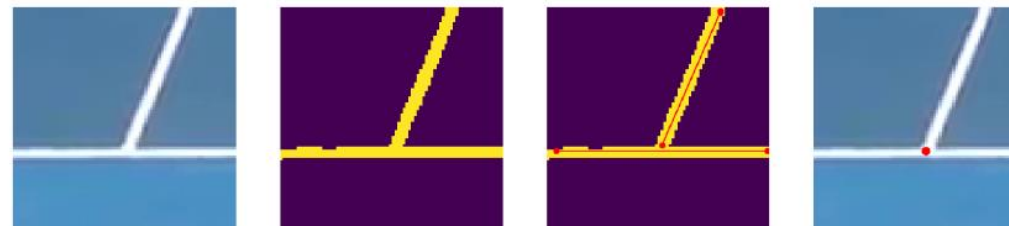
- Court Detection Model



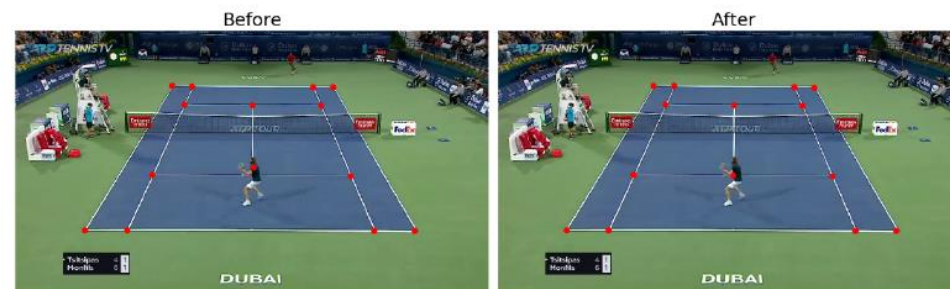
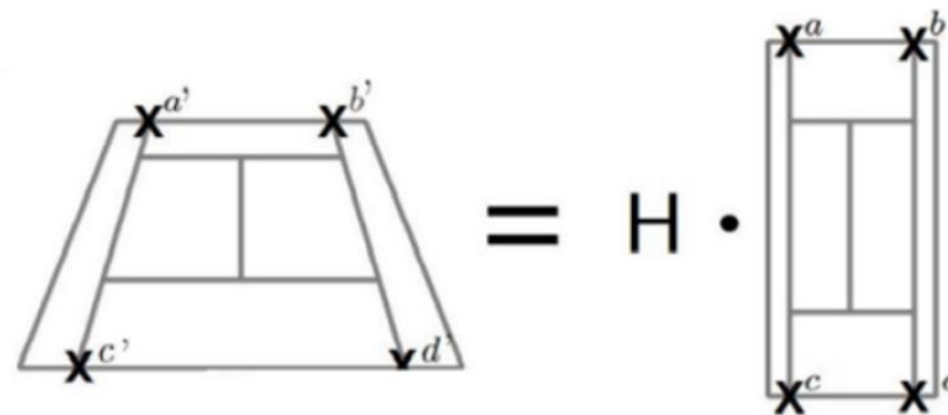
Mini map and dashboard



Model Results



	Precision	Accuracy	Median dist
Base model (BM)	0.936	0.933	2.83
BM + refining kps	0.939	0.936	2.23
BM + homography	0.961	0.959	2.27
BM + refining kps + homography	0.963	0.961	1.83



Model Results

- Player Action Detection



	precision	recall	f1-score	support
Backhand	0.96	0.99	0.98	500
Forehand	0.98	0.96	0.97	500
Ready	0.99	0.98	0.99	500
Serve	1.00	1.00	1.00	500
accuracy			0.98	2000
macro avg	0.98	0.98	0.98	2000
weighted avg	0.98	0.98	0.98	2000

Player vs Player statistics

- **Head-to-Head Wins Bar Chart:**

- Comparison of head-to-head wins between Federer and Nadal.

- **Win Percentage Comparison:**

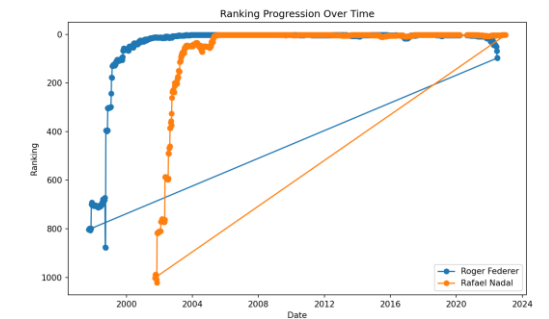
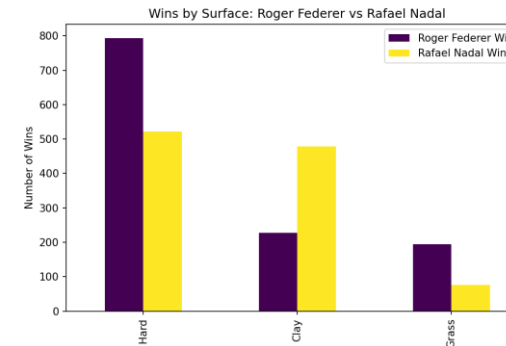
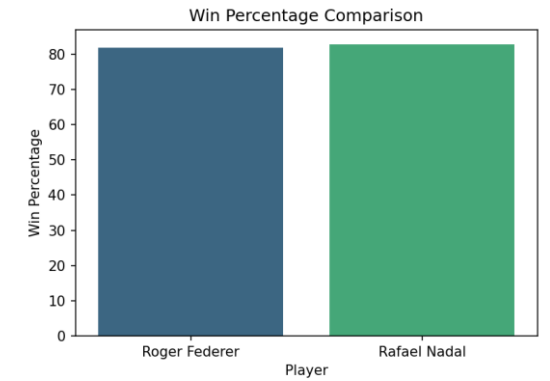
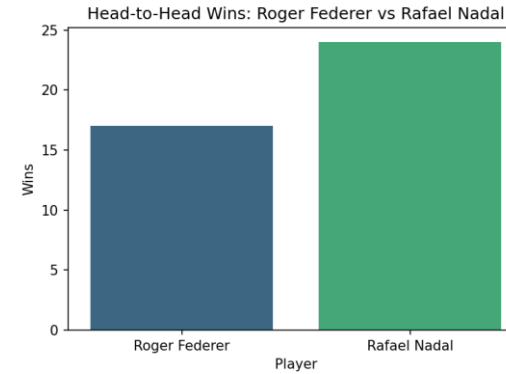
- Bar chart illustrating win percentages of both players.

- **Wins by Surface:**

- Bar chart comparing wins on different surfaces (Hard, Clay, Grass).

- **Ranking Progression:**

- Line chart showing ranking progression over time for both players.



PLAYER VS PLAYER STATISTICS



Player Comparison

Stat	Rafael Nadal	Daniil Medvedev
Nationality	ESP	RUS
Total Matches Played	1302	385
Total Wins	1078	268
Win Percentage	82.79569892473118	69.61038961038962
Current Rank	2	7
Career-High Rank	1	1
Head-to-Head Wins	5	1

Player Overview

Stat	Rafael Nadal	Daniil Medvedev
Full Name	Rafael Nadal Parera	Daniil Sergeyevich Medvedev
Nationality	Spanish	Russian
Date of Birth	1986-06-03	1996-02-11
Height	185	198
Weight	85	83

PLAYER VS PLAYER STATISTICS

Career Highlights

Stat	Rafael Nadal	Daniil Medvedev
Total Career Titles	92	20
Grand Slam Wins	22	1
Olympic Medals	{'goldSingles': 1, 'goldDoubles': 1, 'silver': 0, 'bronze': 0}	N/A
Career Prize Money	\$134640000	\$29564000
Career-High Ranking	1	1
Current Ranking	3	5
Year-End No. 1 Rankings	2008, 2010, 2013, 2017, 2019	

Head-to-Head Records

Stat	Rafael Nadal	Daniil Medvedev
Total matches played	6	6
Wins by Nadal	5	5
Wins by Medvedev	1	1
Wins on Hard	4	1
Wins on Clay	1	0
Wins on Grass	0	0

PLAYER VS PLAYER STATISTICS

Performance Statistics

Stat	Rafael Nadal	Daniil Medvedev
Overall Win Percentage	83.2%	73.4%
Aces	3700	4200
Double Faults	1600	1600
First Serve Percentage	68%	63%
First Serve Points Won	74%	78%
Second Serve Points Won	57%	52%
Break Points Converted	34%	31%
Second Break Points Converted	56%	50%
Tiebreak Record	{'played': 320, 'won': 200}	{'played': 210, 'won': 130}

Tournament History

Tournament	Rafael Nadal	Daniil Medvedev
Australian Open	Winner (2009)	Finalist (2021, 2022)
French Open	Winner (2005-2008, 2010-2014, 2017-2020, 2022)	Quarterfinalist (2021)
Wimbledon	Winner (2008, 2010)	Fourth Round (2021)

PLAYER VS PLAYER STATISTICS

Tournament History

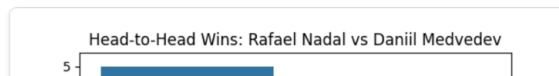
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Wimbledon	Winner (2008, 2010)	Fourth Round (2021)
US Open	Winner (2010, 2013, 2017, 2019)	Winner (2021)
ATP Finals Titles	0	1
Masters Titles	36	6

Historical Trends

- Rafael Nadal Match-Win Streaks: 32
- Daniil Medvedev Match-Win Streaks: 20
- Rafael Nadal Performance Against Top-10 Players: 62.5
- Daniil Medvedev Performance Against Top-10 Players: 55.1
- Rafael Nadal Notable Upsets: Defeated Roger Federer in the 2008 Wimbledon final.
- Daniil Medvedev Notable Upsets: Defeated Novak Djokovic in the 2021 US Open final.

Comparison Visualizations

Head To Head



Win Percentage

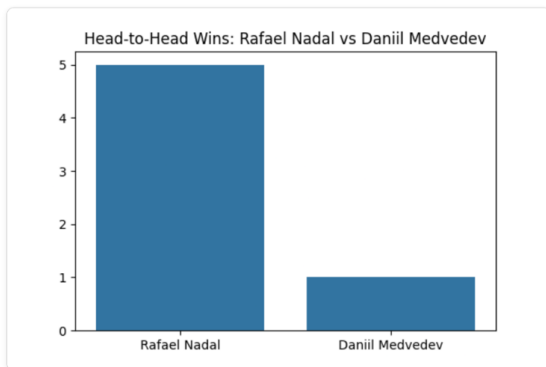


PLAYER VS PLAYER STATISTICS

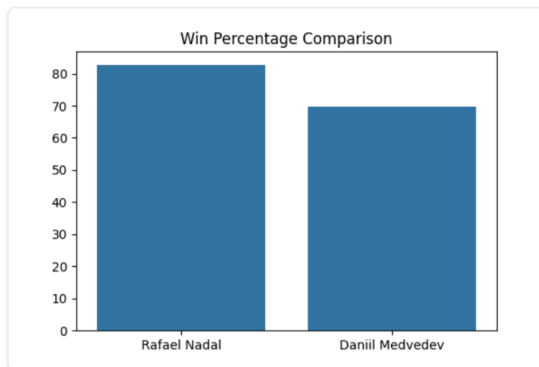
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Comparison Visualizations

Head To Head



Win Percentage



Wins By Surface



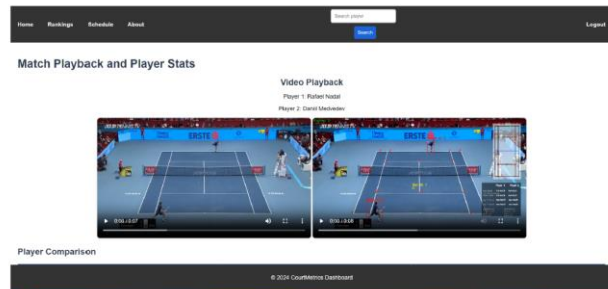
Backend and Frontend Implementation

•Backend:

- Video upload and processing API
- APIs for player ranking, match schedule
- Azure OpenAI service for Player Statistics

•Frontend:

- YouTube Video Downloader & Uploader (Completed)
- Player ranking system
- Match scheduling page



Player Comparison

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© 2024 CourtMetrics Dashboard

Career Highlights

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Grand Slam Wins	22	1
Olympic Medals	(gold/silver/1, silver/0, bronze/0)	NA
Career Prize Money	\$13466000	\$2054000
Career-High Ranking	1	1
Current Ranking	3	5
Year-End No. 1 Rankings	2008, 2010, 2013, 2017, 2019	

Head-to-Head Records

Stat	Rafael Nadal	Daniil Medvedev
Head-to-Head Matches Played	6	6
Head-to-Head Wins	5	5
Head-to-Head Losses	1	1
Wins on Hard	4	1
Wins on Clay	1	0
Wins on Grass	0	0

© 2024 CourtMetrics Dashboard

AZURE OPENAI SERVICE

This screenshot shows the Azure OpenAI Service Chat playground interface. The left sidebar contains navigation options: Home, Get started, Model catalog, Playgrounds, Chat (selected), Assistants (PREVIEW), Real-time audio (PREVIEW), Images, Completions, Tools, Fine-tuning, Azure OpenAI Evaluation (PREVIEW), Batch jobs, Shared resources, Deployments, Quota, Safety + security, Data files, and Vector stores (PREVIEW). The main area is titled "Chat playground" and includes a top bar with "View code", "Deploy", "Import", "Export", "Prompt samples", and "Send feedback". The "Setup" section shows the deployment "gpt-4o (version:2024-08-06)" and a text area with the instruction: "I am building a tennis analytics website. I need a detailed report comparing two players: {{player1_name}} and {{player2_name}}. Please provide the following details in **strict JSON format**. Ensure all fields conform to proper JSON". Below the text area are "Apply changes" and "Generate prompt" buttons. The "Chat history" section is empty, with a "Start with a sample prompt" section offering "Historical fiction", "Travel guide", and "Poetry generation" options. A text input field at the bottom is empty, and the token count shows "528/128000 tokens to be sent".

This screenshot shows the same Azure OpenAI Service Chat playground interface after a prompt has been generated. The "Chat history" section now displays the prompt: "Hello! How can I assist you today?" followed by the user's request: "I need a detailed report comparing two players: rafael Nadal and danil Medvedev". The AI's response is a JSON object: {"Player Overview": [{"Player": "Rafael Nadal", "Nationality": "Spanish", "Date of Birth": "1985-06-03", "Height": 178, "Weight": 75, "Playing Hand": "Right-handed", "Playing Style": "Aggressive baseline player", "Turned Pro Year": 2005}, {"Player": "Daniil Medvedev", "Nationality": "Russian", "Date of Birth": "1991-02-18", "Height": 188, "Weight": 80, "Playing Hand": "Right-handed", "Playing Style": "Aggressive baseline player", "Turned Pro Year": 2010}], "Career Highlights": [{"Player": "Rafael Nadal", "Year": 2005, "Event": "Turned Pro"}, {"Player": "Rafael Nadal", "Year": 2008, "Event": "Wimbledon Champion"}, {"Player": "Rafael Nadal", "Year": 2010, "Event": "Australian Open Champion"}, {"Player": "Rafael Nadal", "Year": 2013, "Event": "Wimbledon Champion"}, {"Player": "Rafael Nadal", "Year": 2017, "Event": "Wimbledon Champion"}, {"Player": "Rafael Nadal", "Year": 2020, "Event": "Wimbledon Champion"}, {"Player": "Daniil Medvedev", "Year": 2010, "Event": "Turned Pro"}, {"Player": "Daniil Medvedev", "Year": 2019, "Event": "Australian Open Champion"}, {"Player": "Daniil Medvedev", "Year": 2021, "Event": "Wimbledon Champion"}]}. The "Chat history" section also shows the AI's response: "Please provide the following details in **strict JSON format**. Ensure all fields conform to proper JSON standards (e.g. use double quotes for keys and values, avoid comments, and provide 'null' for missing data). ### Required Sections 1. **Player Overview**: include the following details for each player: - Full name - Nationality - Date of birth (in YYYY-MM-DD format) - Height (in cm) - Weight (in kg) - Playing hand (e.g., Right-handed or Left-handed) - Playing style (brief description) - Turned pro year 2. **Career Highlights**:". The text input field at the bottom now contains the prompt: "Type user query here. (Shift + Enter for new line)". The token count shows "230/128000 tokens to be sent".

AZURE OPENAI SERVICE

The screenshot displays the Azure AI Foundry Chat playground interface. The top navigation bar includes the text "Azure AI Foundry | Azure OpenAI Service / capstone-project / Chat playground" and a link for "All resources".

The left sidebar contains a navigation menu with the following items: Home, Get started, Model catalog, Playgrounds (expanded), Chat (selected), Assistants (PREVIEW), Real-time audio (PREVIEW), Images, Completions, Tools (expanded), Fine-tuning, Azure OpenAI Evaluation (PREVIEW), Batch jobs, Shared resources (expanded), Deployments, Quota, Safety + security, Data files, and Vector stores (PREVIEW).

The main content area is titled "Chat playground" and features a toolbar with "View code", "Deploy", "Import", "Export", "Prompt samples", and "Send feedback".

The interface is divided into two main sections:

- Setup:** This section allows for configuring the chat environment. It includes a "Deployment" dropdown menu currently set to "gpt-4o (version:2024-08-06)", a "Create new deployment" button, and a text area for "Give the model instructions and context" containing the prompt: "You are an AI assistant that helps people find information." Below this are buttons for "Apply changes" and "Generate prompt", and an "Add section" button.
- Parameters:** This section includes two sliders: "Past messages included" (set to 10) and "Max response" (set to 1900).

The right section is the "Chat history", which shows a JSON response from the model:

```
{
  "players": {
    "rafaelNadal": {
      "playerOverview": {
        "fullName": "Rafael Nadal Parera",
        "nationality": "Spanish",
        "dateOfBirth": "1986-06-03",
        "height": 185,
        "weight": 85,
        "playingHand": "Left-handed",
        "playingStyle": "Aggressive baseline player with heavy topspin",
        "turnedProYear": 2001
      },
      "careerHighlights": {
        "totalCareerTitles": 92,
        "grandSlamWins": 22,
        "olympicMedals": {
```

Below the chat history is a text input field with the placeholder "Type user query here. (Shift + Enter for new line)". At the bottom right of the chat history area, it indicates "1135/128000 tokens to be sent" along with icons for chat, voice, and a stop button.

CHALLENGES & SOLUTIONS

- **Model Accuracy:**

- Issue: Lighting and camera angle variations
- Solution: Extra testing and data collection

- **Backend Performance:**

- Issue: Video upload latency
- Solution: Optimized code and implemented load balancing

THANK YOU

