COURTMETRICS – UNLOCKING TENNIS INSIGHTS WITH MACHINE LEARNING

Team Members:

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Lokesh Devendra Satpute

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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/1lhAaeQCmk2y440PmagA0KmIVBIysVMwu/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)

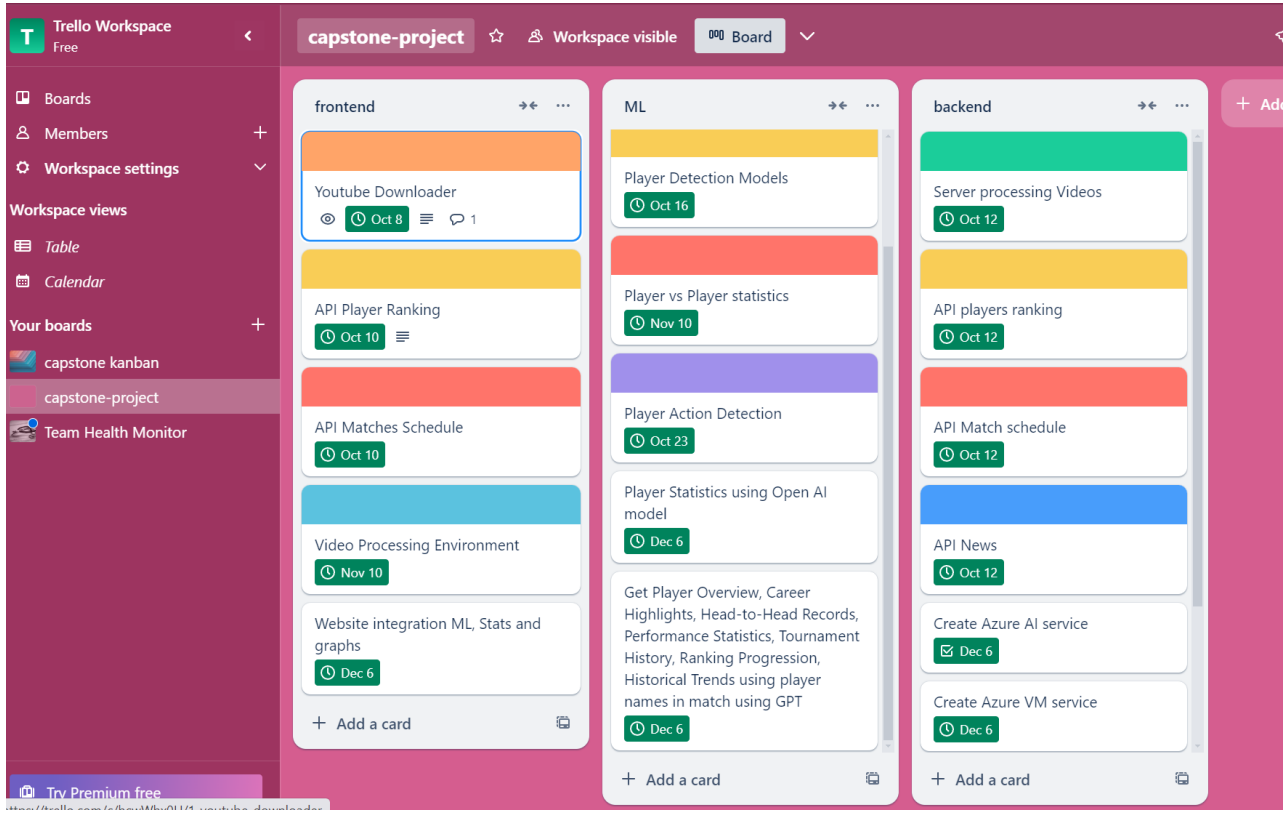
We use COCO-Annotator to annotating and categorizing human actions

- ["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/nv3rpsxhhk/1

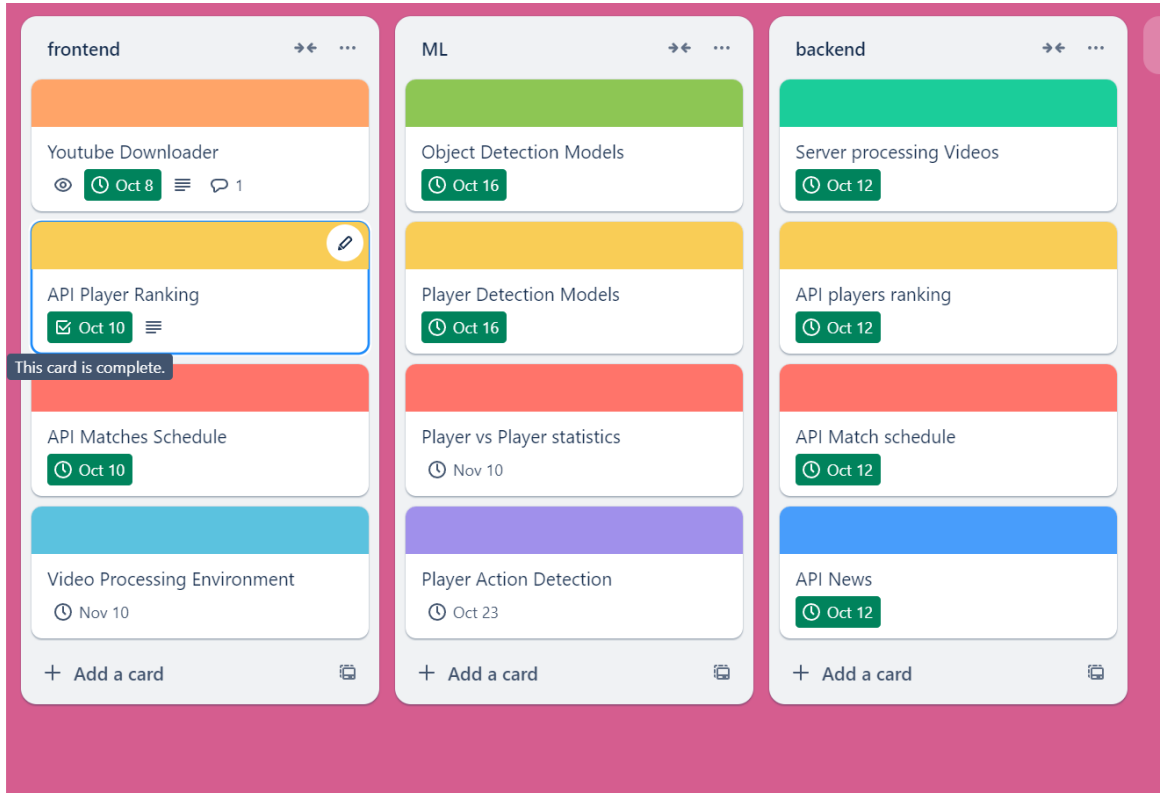
Tools

- 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


Trello Workspace
Free
capstone-project
Workspace visible
Board
Boards
Members
Workspace settings
Workspace views
Table
Calendar
Your boards
capstone kanban
capstone-project
Team Health Monitor
Try Premium free
frontend
Youtube Downloader
Oct 8
1
API Player Ranking
Oct 10
API Matches Schedule
Oct 10
Video Processing Environment
Nov 10
Website integration ML, Stats and graphs
Dec 6
Add a card
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
Add a card
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
Add a card

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

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

•**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)

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

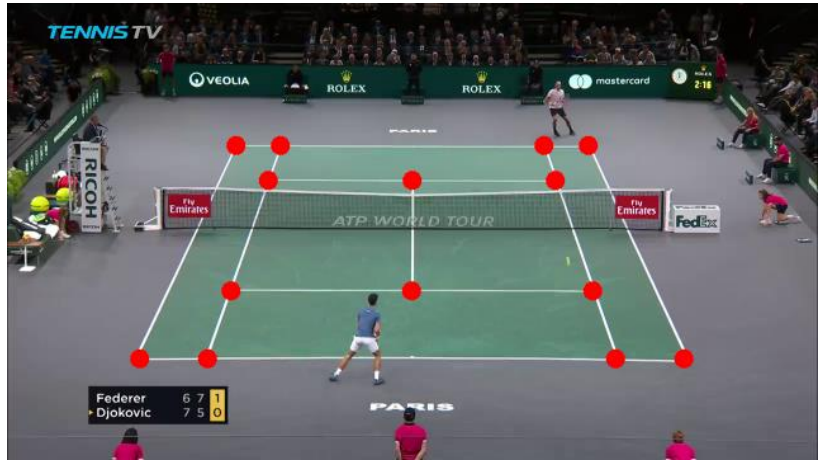
	Category	Task	Status	Assigned To	Due Date
1	Frontend	YouTube Downloader	Completed on Oct 8	Gautham	Oct 8
2	Frontend	API Player Ranking	Completed on Oct 10	Ashutosh	Oct 10
3	Frontend	API Matches Schedule	Completed on Oct 10	Lokesh	Oct 10
4	Frontend	Login and Signup Pages	Completed on Nov 25	Atharva	Nov 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

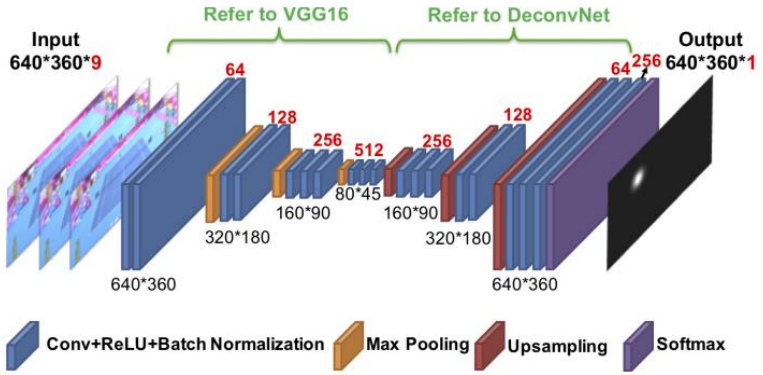
	A	B	C	D	E	F
1	**User Story**	**Priority**	**Task (Summary)**	**Description**	**Total Time Estimated (hrs)**	**Status**
2	Upload Match Video	High	Develop video upload API, file validation, and test video	Upload match video for analysis	13	Completed in Sprint 1
3	View Match Analysis	High	Design dashboard, 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

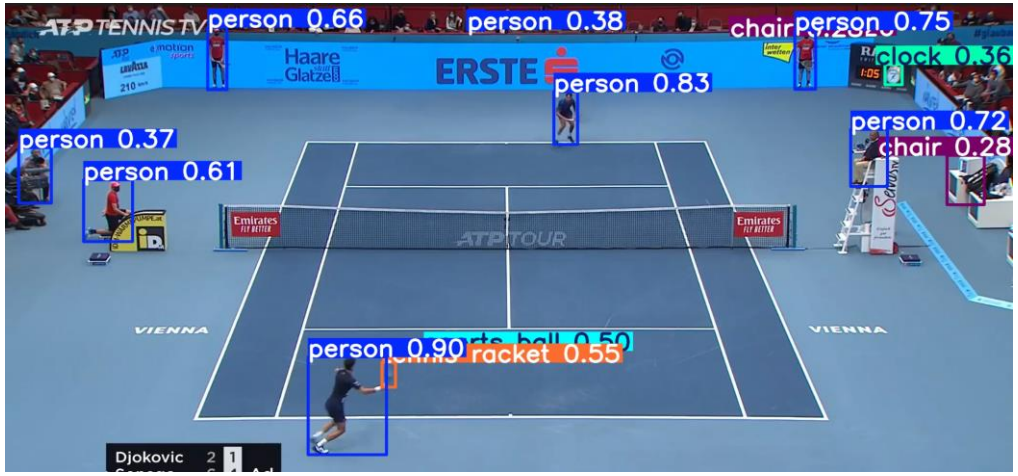
Model Architecture



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

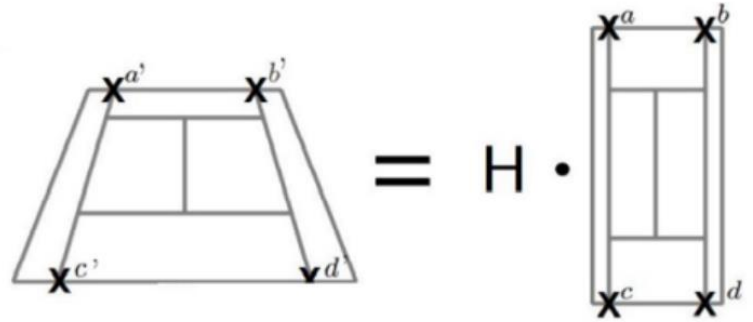


Model Architecture



- **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:**

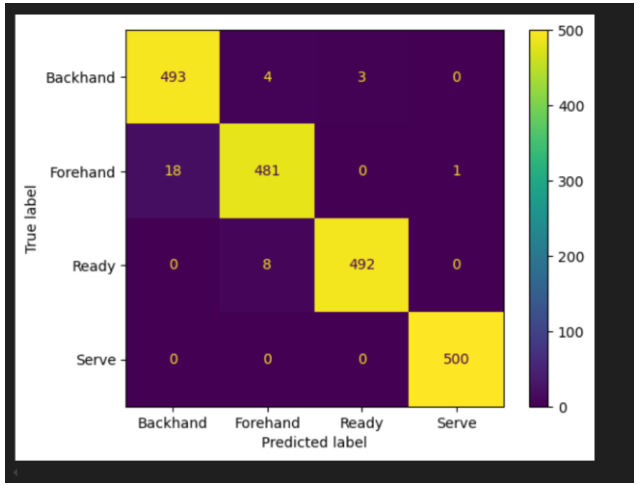
•Extract white pixels, detect lines, and use intersections to correct predictions.

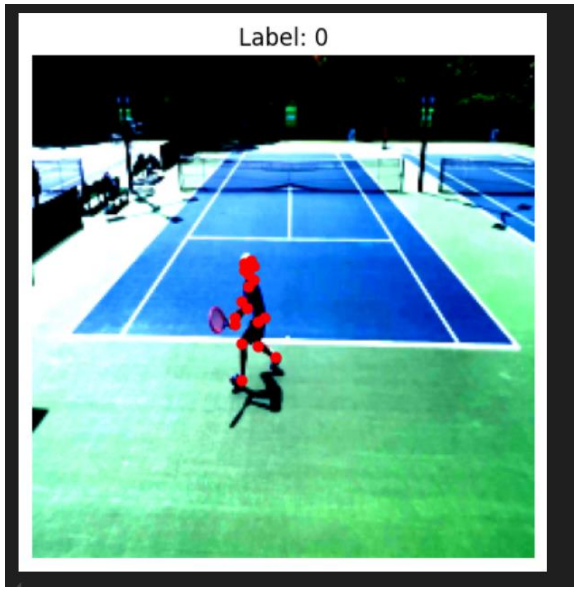
•**Homography Adjustment:**

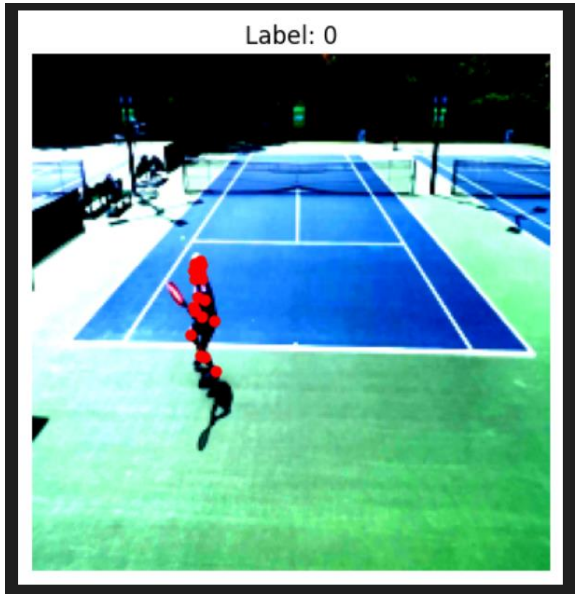
•Apply homography matrix to compare and shift predicted keypoints for occluded areas.

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.







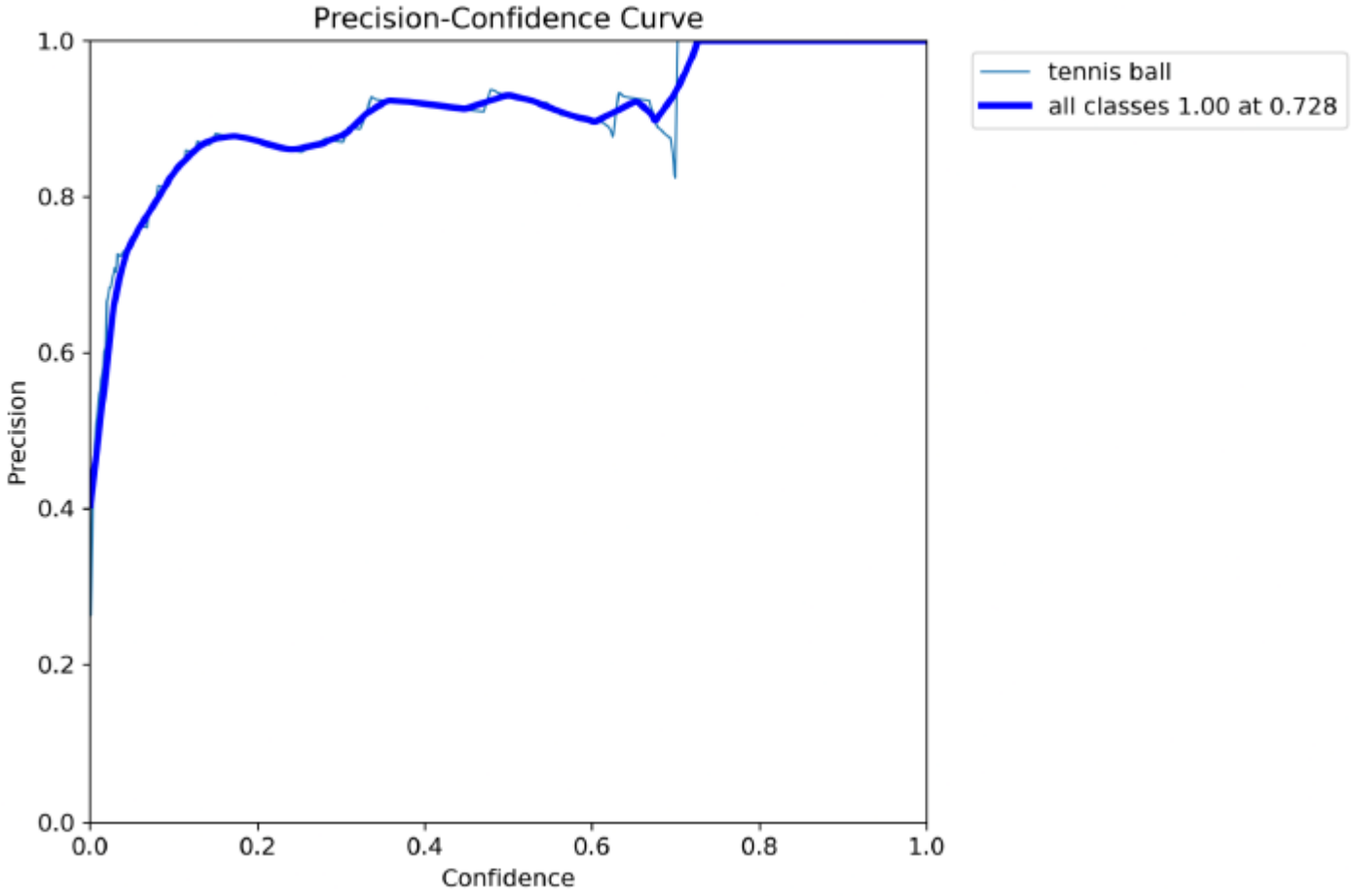
Model Results

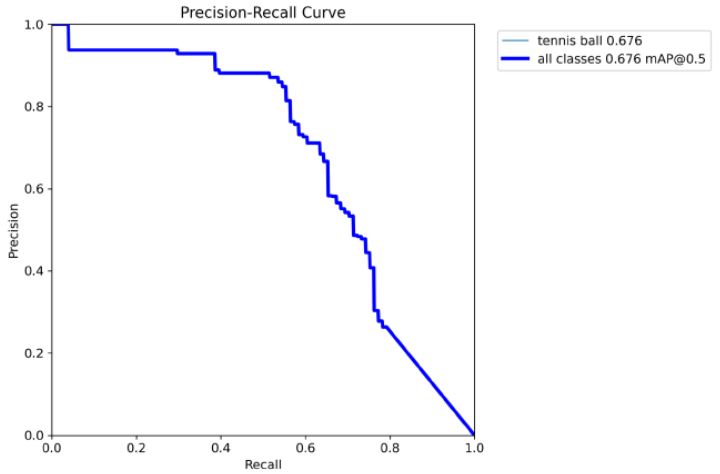
- **Tennis Ball Detection Model:**

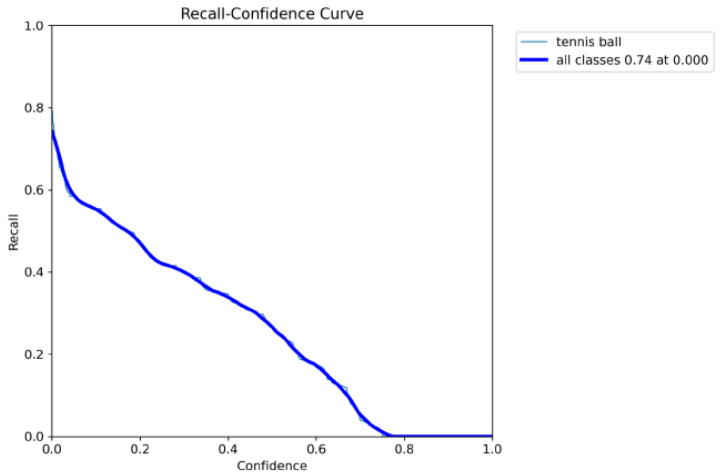
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1
1	epoch	time	train/box_loss	train/cls_loss	train/dfl_loss	metrics/precision(B)	metrics/recall(B)	metrics/mAP50(B)	metrics/mAP50-95(B)	val/box_loss	val/cls_loss	val/dfl_loss	lr/pg0	lr/pg1	lr/pg2	
2	95	57814.1	1.87632	0.86355	0.83886	0.67078	0.52451	0.58526	0.24342	2.11677	1.11245	0.7181	0.0001388	0.0001388	0.0001388	
3	96	58326.4	1.99191	0.85685	0.84592	0.69531	0.54228	0.62416	0.26516	1.98092	1.0531	0.71072	0.000119	0.000119	0.000119	
4	97	58839.6	1.82771	0.82261	0.83149	0.69858	0.55446	0.62449	0.26194	1.92023	1.06135	0.70793	9.92E-05	9.92E-05	9.92E-05	
5	98	59352.8	1.81676	0.83848	0.82499	0.70317	0.56292	0.62727	0.27207	1.87217	1.04691	0.70678	7.94E-05	7.94E-05	7.94E-05	
6	99	59866.9	1.89667	0.87752	0.86029	0.71471	0.55446	0.62781	0.27814	1.81555	1.01385	0.70546	5.96E-05	5.96E-05	5.96E-05	
7	100	60381.1	1.83433	0.81639	0.83446	0.72426	0.55446	0.6417	0.27628	1.83605	1.01314	0.70568	3.98E-05	3.98E-05	3.98E-05	
8																

Model Results

- **Tennis Ball Detection Model:**







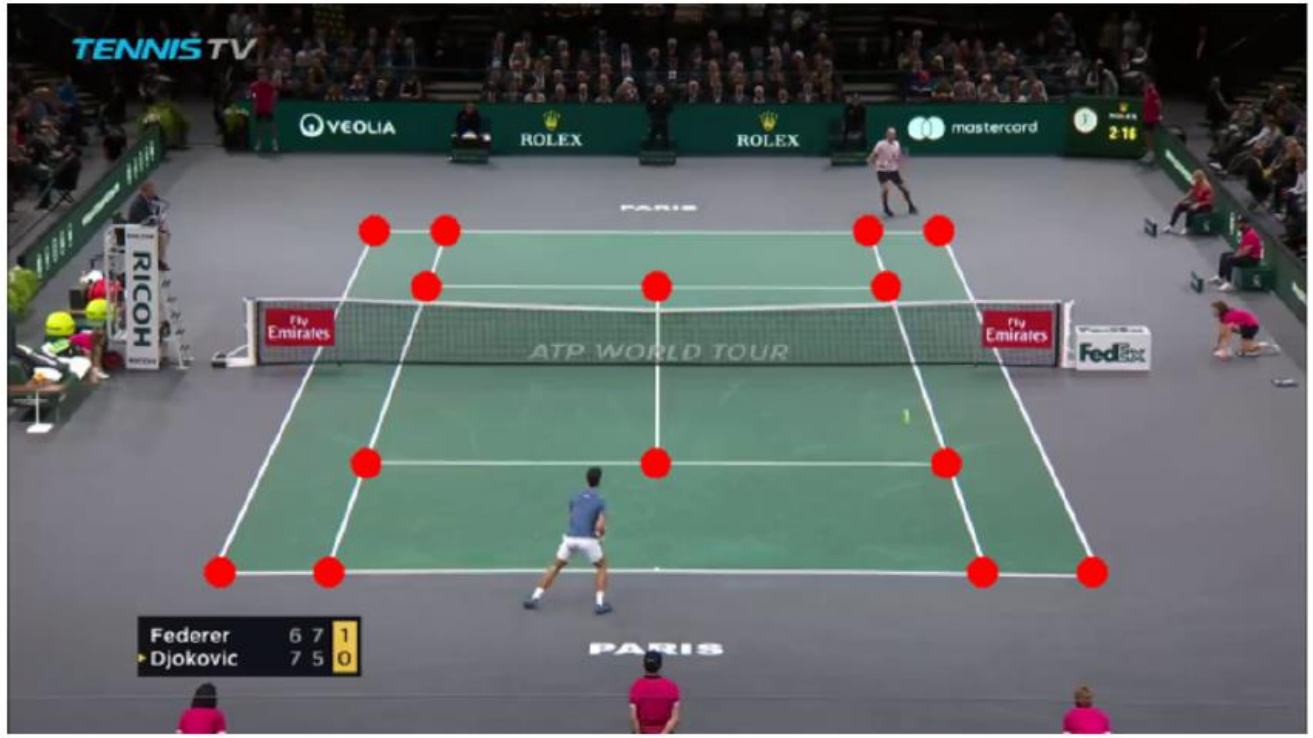
Model Results

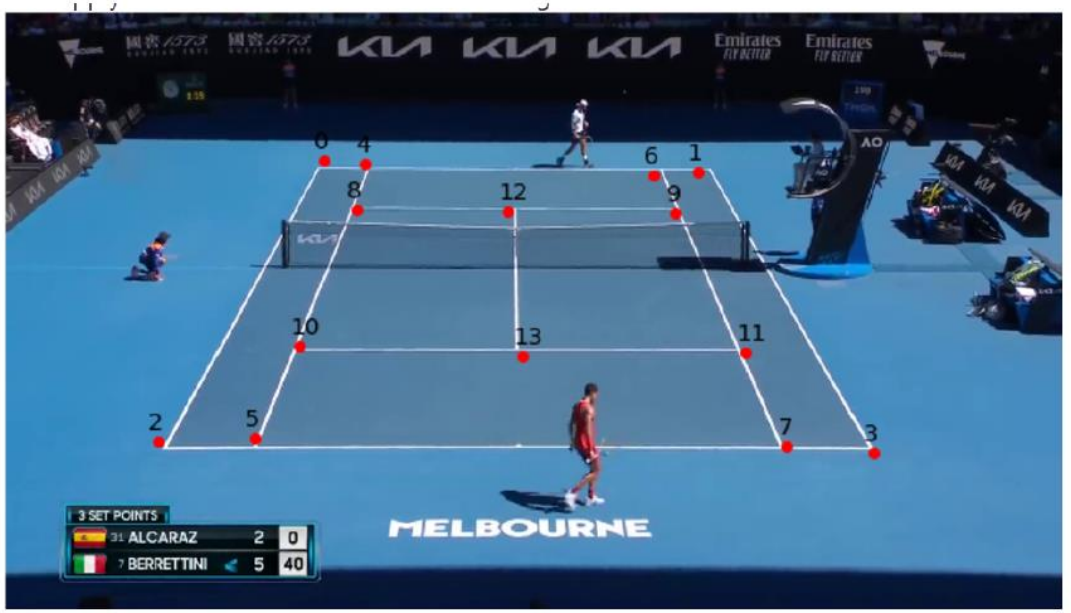
- **Tennis Player Detection:**

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

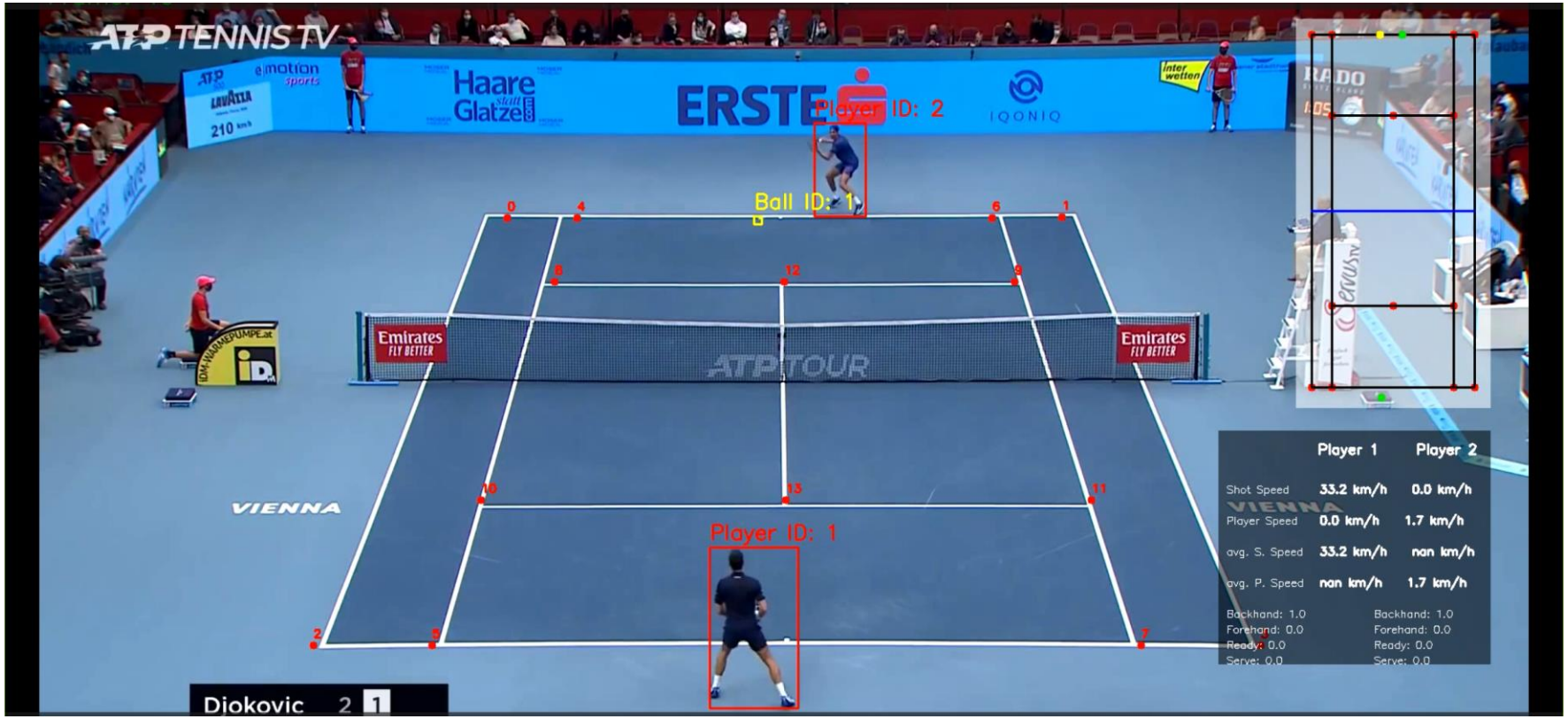
Model Results

- Court Detection Model

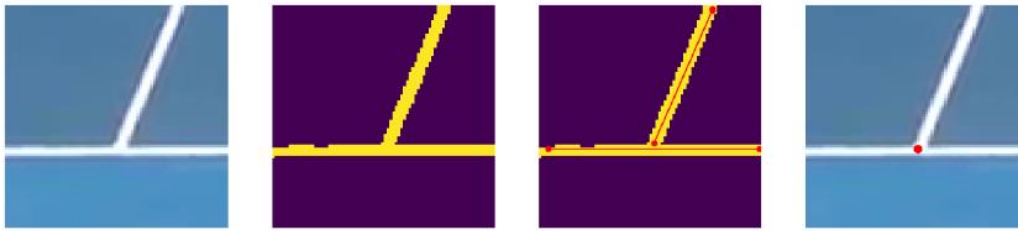




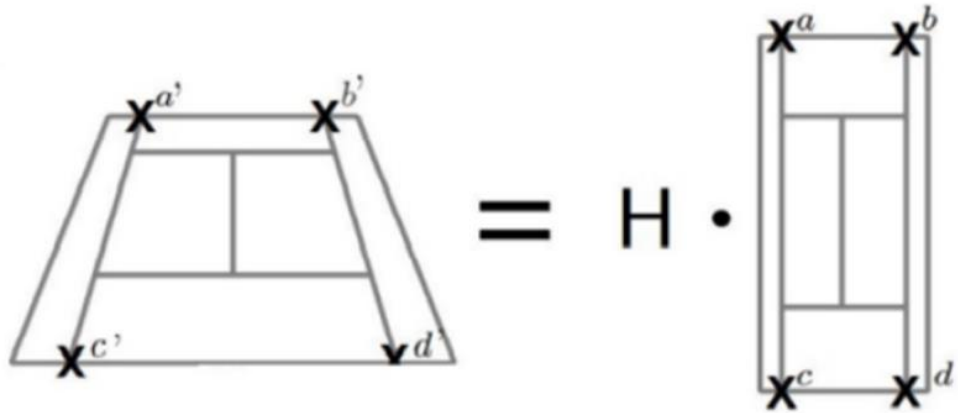
Mini map and dashboard

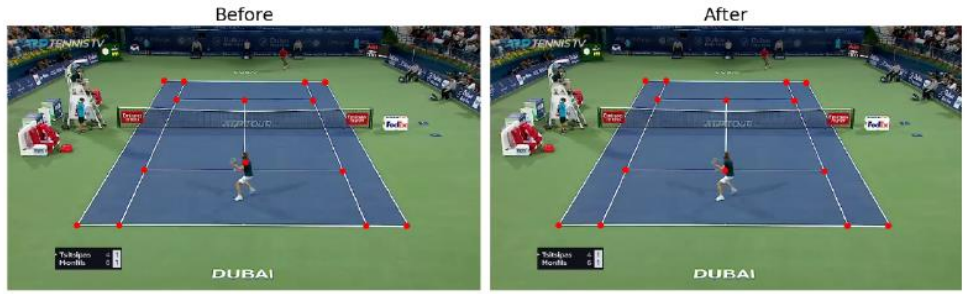


Model Results



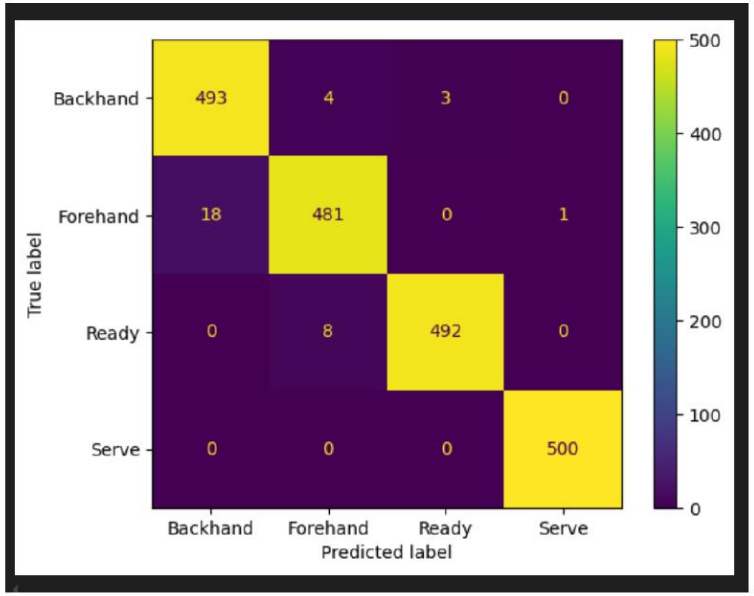
	Precision	Accuracy	Median dist
Base model (BM)	0.936	0.933	2.83
BM + refining kps	0.939	0.936	2.23
BM + homography	0.961	0.959	2.27
BM + refining kps + homography	0.963	0.961	1.83





Model Results

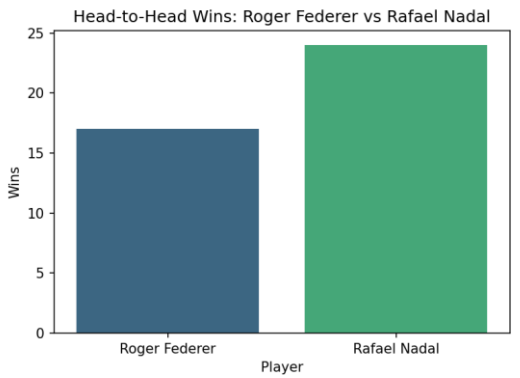
- Player Action Detection

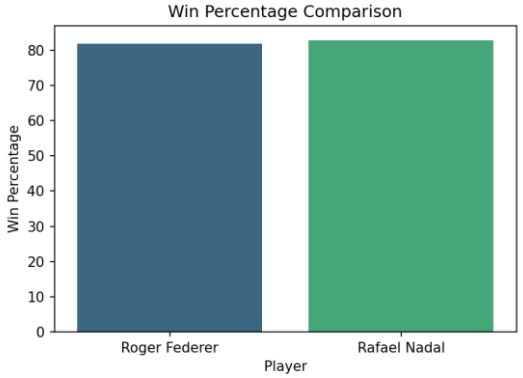


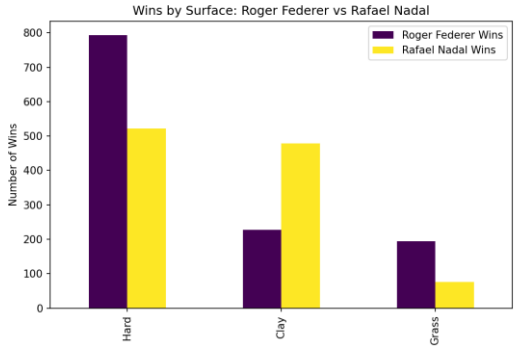
	precision	recall	f1-score	support
Backhand	0.96	0.99	0.98	500
Forehand	0.98	0.96	0.97	500
Ready	0.99	0.98	0.99	500
Serve	1.00	1.00	1.00	500
accuracy			0.98	2000
macro avg	0.98	0.98	0.98	2000
weighted avg	0.98	0.98	0.98	2000

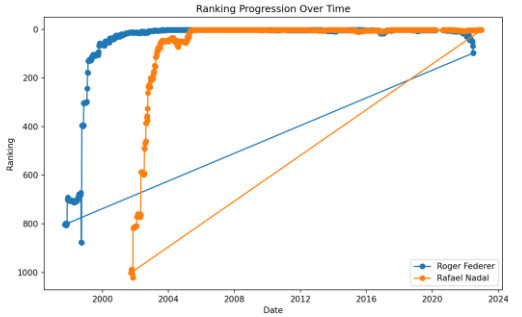
Player vs Player statistics

- **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
Totalmatchesplayed	6	6
Winsbynadal	5	5
Winsbymedvedev	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

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French Open	Winner (2005-2008, 2010-2014, 2017-2020, 2022)	Quarterfinalist (2021)
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

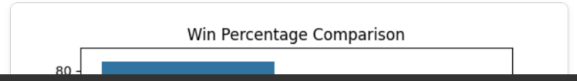
Historical Trends

- 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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- Daniil Medvedev Performance Against Top-10 Players: 55.1
- Rafael Nadal Notable Upsets: Defeated Roger Federer in the 2008 Wimbledon final.
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Comparison Visualizations

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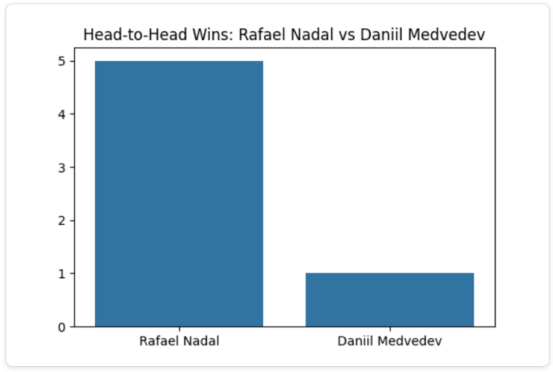
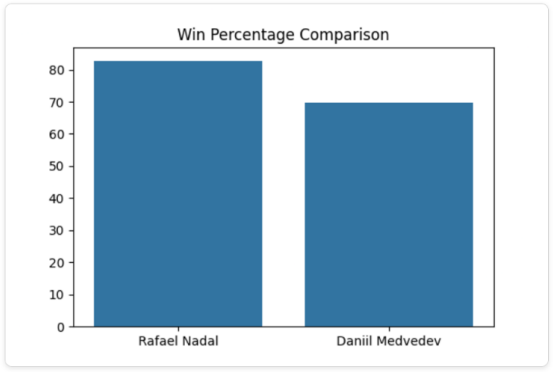


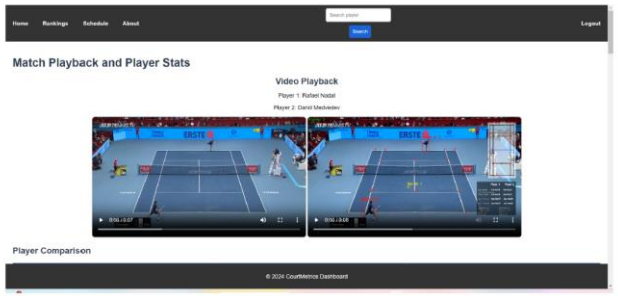
Win Percentage



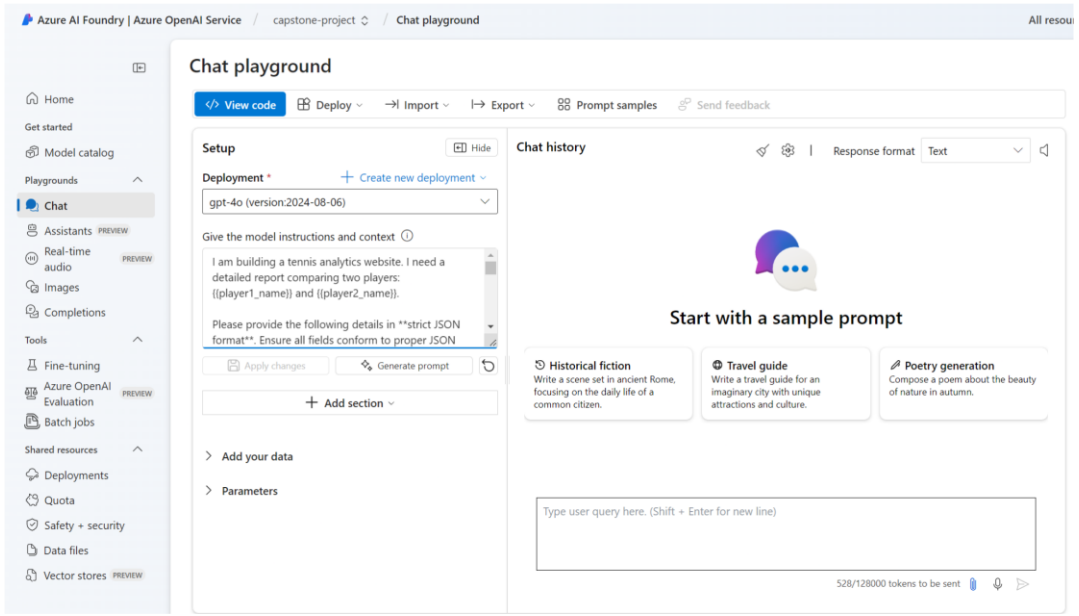
Wins By Surface

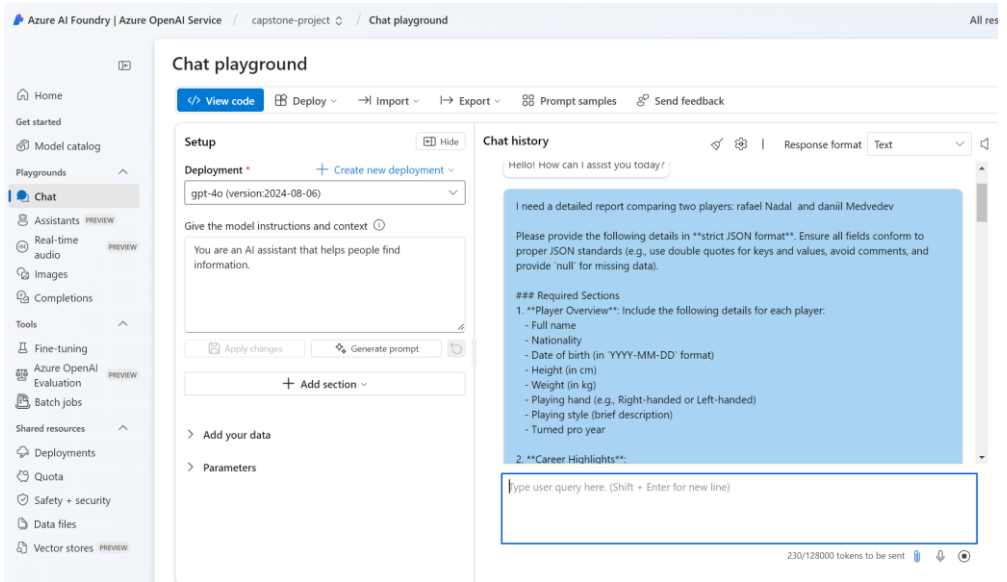
Backend and Frontend Implementation

- **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

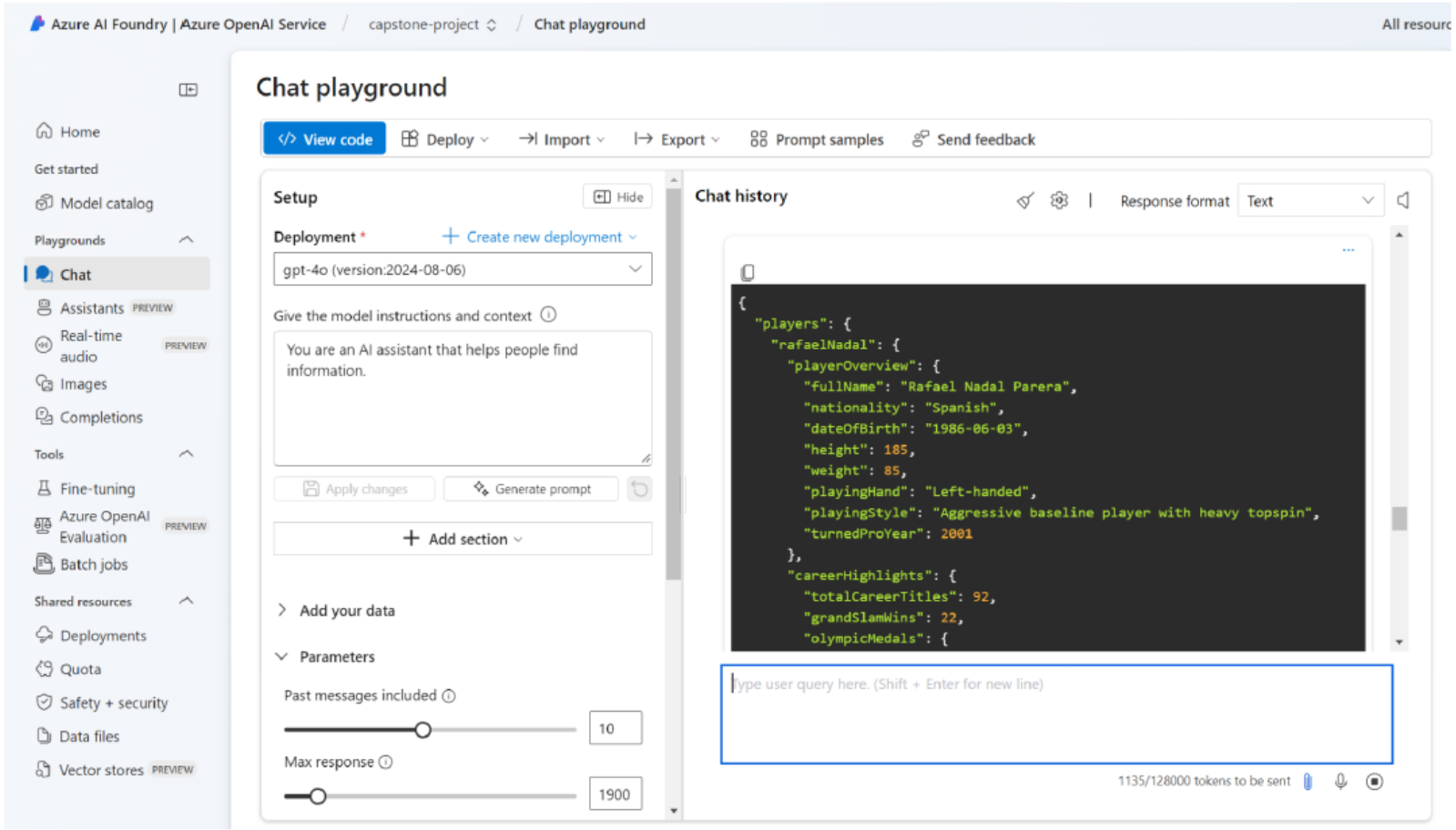


AZURE OPENAI SERVICE





AZURE OPENAI SERVICE



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