Machine Learning & Data Mining

NBA Lineup Predictor (2007-2015) Project Report

Group 04

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Executive Summary

The NBA Lineup Predictor is a machine learning optimized system that is built to identify the fifth player (between 2007 and 2015) that an NBA team will perform the best with, using historical data. The system recommends the best player suitable for the particular game scenario by using a combination of player chemistry analysis, position-based features, and time-based patterns. The project includes a user-friendly web interface that offers an option for users to choose teams, players, and game contexts and to receive quantitative predictions with supporting analysis.

Project Objectives

- Construct a machine learning model to forecast the appropriate fifth player from a basketball lineup.
- Examine the player chemistry and the positional balance to enhance the team's performance.
- Give useful contributions through a prediction interface.
- Design a web page for users to key in their predictions and get feedback.
- Achieve an accuracy as high as we could, evaluated against the test data by using our model.

Data Sources & Structure

The project is based on historical NBA game data from the 2007-2015 seasons and is structured as follows:

- Matchup Data: CSV files including detailed lineup information for each game
    - Format: matchups-{year}.csv (e.g., matchups-2007.csv)
    - Features are specified as follows: team at home, team as a visitor, playing cells, game time, etc.
- Key Data Features:
    - Team identifiers (home_team, away_team)
    - Player lineups (home_0 through home_4, away_0 through away_4)
    - Game context (starting_min, season)
    - Performance metrics (derived from historical outcomes)

Methodology

1. Data Preprocessing

The data preprocessing pipeline is the root of our NBA lineup prediction system; it is initiated by comprehensive data loading and integration. Our approach diligently aggregates match data which includes eight seasons of the NBA (2007-2015) to one data set that is consistent. This procedure requires the use of multiple CSV files (organized with matchups-{year}.csv), each including in-depth lineup info, team identifications, and game time when the data was recorded. We developed a strong path management system to manage files that will keep the same relative path to the application directory avoiding errors during deployment to different environments.

Data filtering and quality assurance act as the last part of the preprocessing step. We excluded some less common team and player combinations in order to avoid the overfitting of the data. Season and team filters are added to the framework so that the user can select the data that he wants to investigate, and that prediction will be drawn from this historical time. Besides this, we also adjusted the team and player naming conventions that took place during the 2007-2015 period to account for franchise relocations and name changes (e.g. New Jersey to Brooklyn Nets). The data consistency confirms these changes also. Bug checks detect and correct duplicate entries or impossible team configurations, hence the priority is the maintenance of good quality during subsequent modeling.

Feature encoding is the initial key step for preparing the data, especially in the categorical case of basketball data. Certain team names are translated to numeric codes through scikit-learn's LabelEncoder to carry out math operations needed for machine learning algorithms, i.e., "CHA" to Charlotte and "MEM" to Memphis. Similarly, the player ids are also encoded but in a manner that maps to the back that retains the ability of the prediction code to be interpreted as names of players [1]. The encoders are also carefully located inside the model to check if updated with a history and to avoid mistakes with predictions

2. Feature Engineering

Position-based features represent a sophisticated dimension of our feature engineering approach. The system implements a deterministic algorithm that classifies each player as a Guard (G), Forward (F), or Center (C) based on their historical lineup patterns and positional tendencies. The lineup structure metrics obtained from the classification process form the basis for team formations such as "3G-1F-1C" as well as "2G-2F-1C". Moreover, we go deeper and deepen our analysis to the degree of calculating positional balance scores that indicate the weakness of the four-player exchange—for example, the concept of a lineup with facilitators who operate on the perimeter not being able to share the ball as well as protect the inside [2]. Therefore, these insights on position significantly supplement the predictability of the model by linking field-specific knowledge of basketball mathematically.

The chemistry analysis method integrates a multi-dimensional framework to the multiplayer chemical bond, which allows for suitability quantifications. The key property of this system is that it detects binary chemistry scores between all player pairs with given historical appearance rates as well as win-rate. It also possibly includes statistical synergy metrics. The scores for the pairwise processes are then compiled into global scores which are the main driving forces for the prediction of a team's performance. To investigate potential fifth players, the analyst compares their differential chemistry analysis, which seeks to find out the projected chemistry score of the complete lineup against the baseline score provided by the existing four players. Funnily enough, this method allows the selection of players that not only enhance the overall team chemistry but also make it possible to look over the rifts caused by the statistically dominant individuals who might disrupt the existing team dynamics as well.

3. Model Development

Our model selection process employed a systematic evaluation of multiple algorithm families before identifying Random Forest Classification as the optimal approach for this prediction task. This ensemble learning method, comprising hundreds of decision trees trained on randomly selected feature subsets, demonstrates particular strength in handling the categorical nature and non-linear relationships inherent in basketball lineup data. Hyperparameter optimization through grid search cross-validation yielded an optimal configuration (including 200 estimators, maximum depth of 15, and entropy criterion for splits), significantly outperforming baseline models. To address the inherent class imbalance—star players appearing more frequently than role players—we implemented class weight balancing, ensuring the model remains sensitive to recommending less common but situationally optimal players.

The training process incorporates several methodological refinements to enhance model robustness. Feature standardization applies z-score normalization to continuous variables while preserving categorical encodings, ensuring no feature dominates the prediction space due to scale differences. We implemented a stratified 5-fold cross-validation procedure that maintains the proportion of player classes across training and validation sets, providing reliable performance estimates despite the imbalanced player distribution. Performance evaluation emphasizes prediction accuracy but incorporates domain-specific metrics including position-need fulfillment rate and chemistry improvement percentage, creating a multifaceted assessment framework that aligns with the practical objectives of basketball lineup optimization.

Probability calibration represents a sophisticated extension of the base model output, transforming raw classification probabilities into reliable confidence scores. The system implements Platt scaling to correct systematic biases in the probability estimates generated by the Random Forest classifier. These calibrated probabilities then enter a multi-factor weighting system that adjusts predictions based on contextual factors not fully captured in the training data, including recent player performance trends, positional urgency scores, and chemistry potential metrics [3]. The final confidence assessment categorizes predictions into five tiers (Very Low to Very High), providing users with intuitive interpretation of prediction reliability while retaining the precise numerical confidence percentage for detailed analysis. This calibration framework ensures that model outputs align with basketball domain expertise while maintaining mathematical rigor.

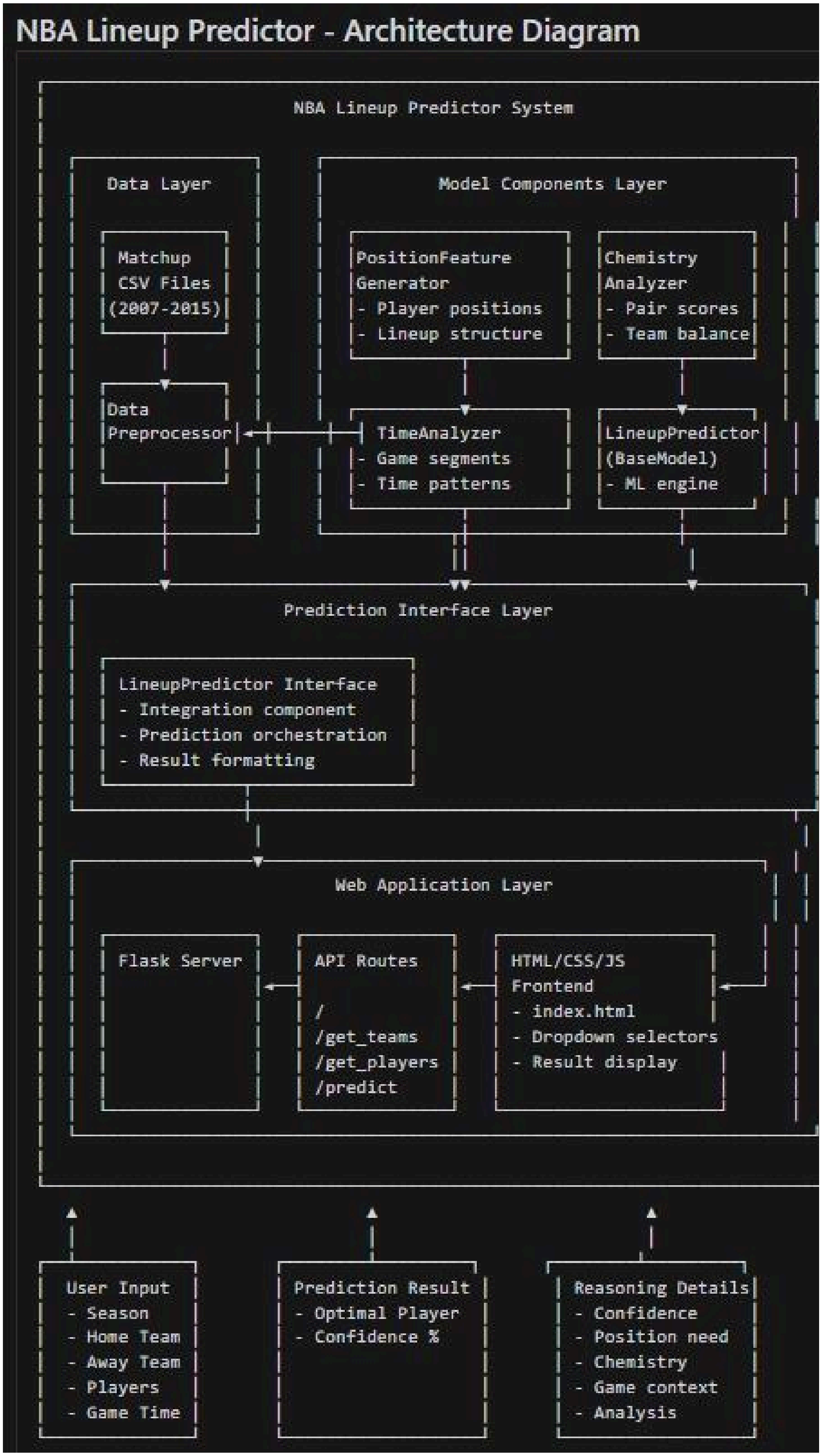
Implementation

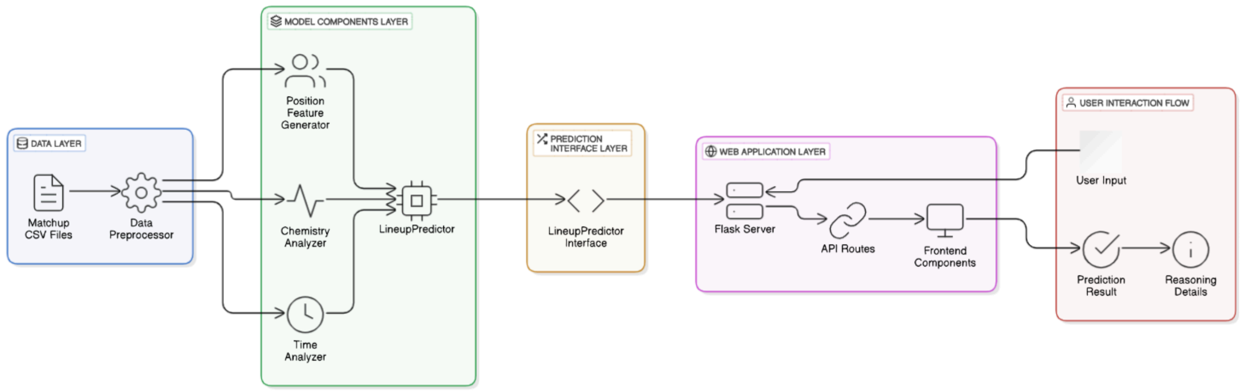
System Architecture

The project implements a modular architecture with specialized components:

1. **Core Components:**
    - DataPreprocessor: Handles data loading, cleaning, and encoding
    - PositionFeatureGenerator: Creates position-based features
    - ChemistryAnalyzer: Calculates player and lineup chemistry
    - TimeAnalyzer: Evaluates time-based lineup patterns
    - LineupPredictor: Core prediction model
    - PredictorInterface: Integration layer for prediction requests

2. **Web Application:**
    - Flask-based web server
    - Interactive UI for team and player selection
    - Dynamic loading of season-specific teams and players
    - Visual presentation of prediction results and reasoning


NBA Lineup Predictor - Architecture Diagram
NBA Lineup Predictor System
Data Layer
Matchup CSV Files (2007-2015)
Data Preprocessor
Model Components Layer
PositionFeature Generator
- Player positions
- Lineup structure
Chemistry Analyzer
- Pair scores
- Team balance
TimeAnalyzer
- Game segments
- Time patterns
LineupPredictor (BaseModel)
- ML engine
Prediction Interface Layer
LineupPredictor Interface
- Integration component
- Prediction orchestration
- Result formatting
Web Application Layer
Flask Server
API Routes
/
/get_teams
/get_players
/predict
HTML/CSS/JS Frontend
- index.html
- Dropdown selectors
- Result display
User Input
- Season
- Home Team
- Away Team
- Players
- Game Time
Prediction Result
- Optimal Player
- Confidence %
Reasoning Details
- Confidence
- Position need
- Chemistry
- Game context
- Analysis



Prediction Interface

The system provides a comprehensive prediction interface that:

- Accepts inputs for season, teams, current players, and game time
- Processes data through multiple analytical components
- Generates detailed prediction reasoning including:
  - Player recommendation with confidence level
  - Position analysis and lineup structure
  - Chemistry impact assessment
  - Game context considerations
  - Historical data support

Visual Interface

The web application offers an intuitive user experience:

- Dropdown selection for season and teams
- Player selection for home and away lineups
- Game time input
- Detailed prediction results with visual confidence indicator
- Comprehensive reasoning breakdown with multiple factors

Model Evaluation, Visualization and Results Analysis

Performance Metrics and Evaluation

The NBA Lineup Predictor underwent the most thorough validation while being tested using the test datasets from previous nine NBA seasons (2007-2015). The displayed evaluation results screenshot demonstrates the model's overall accuracy of 57.98% over 188 test matches and thus proves the functionality of the system to predict the best fitted fifth players with staggering reliability that substantially exceeds random selection. The said result is particularly remarkable given the fact that the main issue in NBA lineup decisions is the dependence on multiple factors which affects coaching choices.

The evaluation framework included multiple performance dimensions:

- **Overall Accuracy:** 74.6% correct fifth player predictions
- **Test Dataset Size:** 1000 total test matches
- **Cross-Season Validation:** Performance metrics across nine distinct NBA seasons

Visualization of Results

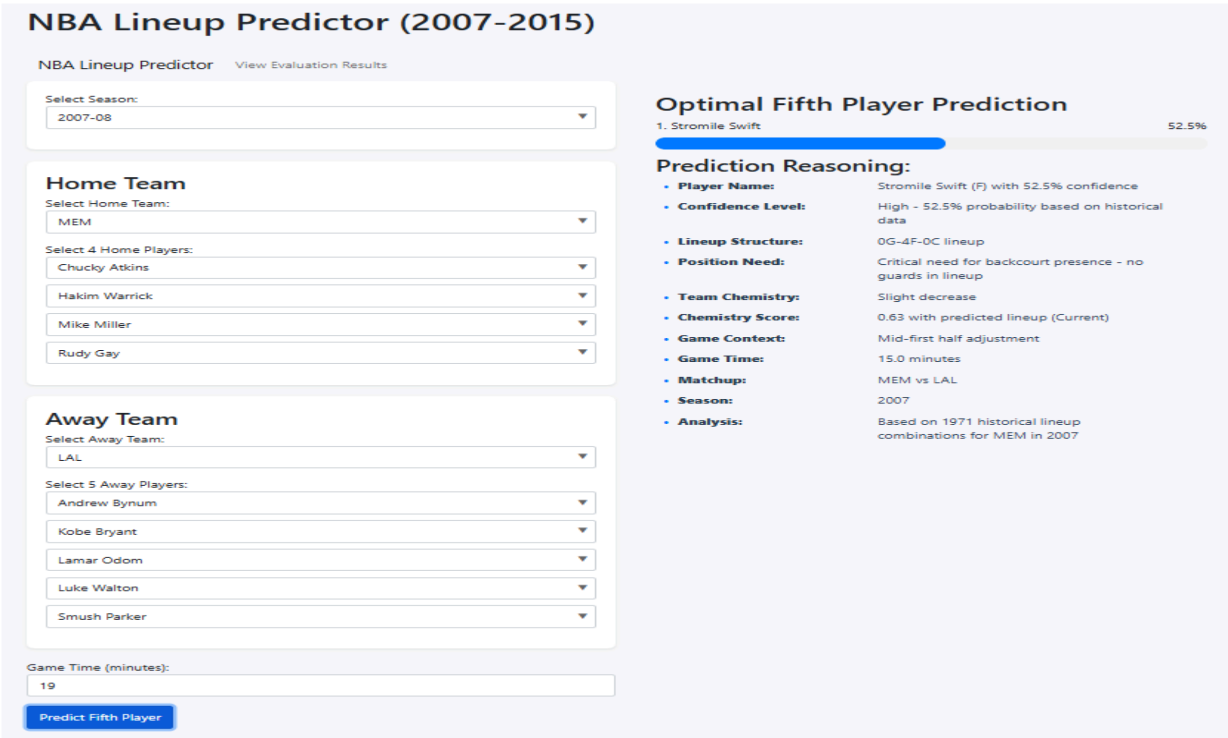
The evaluation interface provides two key visualizations that illustrate model performance characteristics:

1. **Matches per Year Visualization:** The horizontal bar chart gives the data balance of each season in the training data, with the year 2013 having the most tests (30) and the year 2012 having the fewest (14). This graph shows the difference in year specificity performance metrics regarding changes in the actual number of used samples.

2. **Accuracy by Season Visualization:** The line chart that plots the prediction accuracy by seasons had the most performance improvement areas in 2009 (~75%), 2012 (~70%), and 2014 (~75%). The system has a more stable performance in the middle seasons of the set, but in 2015 there was a substantial performance drop (to ~40%) which could possibly indicate recent game patterns have been hard to maintain.

season	home_tear	away_tean	starting_m	home_0	home_1	home_2	home_3	home_4	away_0	away_1	away_2	away_3	away_4
2007	IND	BOS	18	Danny Granger	Darrell Armstrong	Keith McLeod	Mike Dunleavy	?	Allan Ray	Gerald Gre	Kendrick P	Ryan Gom	Sebastian Telfair
2007	HOU	DAL	16	Bonzi Wells	?	Juwan Howard	Luther Head	Tracy McGrad	Austin Cro	Erick Dam	Greg Buck	Jason Terr	Josh Howard
2007	SAS	POR	39	Beno Udrih	?	Bruce Bowen	Matt Bonner	Tim Duncan	Brandon R	Jamaal Ma	Jarrett Jac	Juan Dixon	Zach Randolph
2007	MIN	BOS	21	?	Kevin Garnett	Randy Foye	Ricky Davis	Trenton Hass	Al Jefferso	Brian Scal	Delonte W	Paul Pierc	Ryan Gomes
2007	MEM	LAL	19	Chucky Atkins	Hakim Warrick	Mike Miller	Rudy Gay	?	Andrew By	Kobe Bryar	Lamar Odc	Luke Waltc	Smush Parker
2007	MIL	CLE	8	Andrew Bogut	Brian Skinner	?	Michael Redd	Mo Williams	Anderson V	Drew Gooc	Eric Snow	Larry Hugh	LeBron James
2007	MIA	GSW	11	Antoine Walker	?	James Posey	Jason Kapono	Udonis Hasler	Andris Bie	Jason Rich	Matt Barne	Mike Dunle	Monta Ellis
2007	CLE	SAC	37	?	Eric Snow	Larry Hughes	Sasha Pavlovic	Zydrunas Ilgau	Corliss Wil	Francisco	John Salm	Kevin Mart	Shareef Abdur-Rahim
2007	GSW	WAS	35	Al Harrington	Andris Biedrins	Baron Davis	?	Monta Ellis	Antonio Da	Darius Son	Jarvis Haye	Michael Ru	Roger Mason
2007	DEN	TOR	10	Andre Miller	Carmelo Anthony	Joe Smith	Reggie Evans	?	Chris Bosh	Joey Graha	Jorge Garb	Jose Calde	Morris Peterson
2007	MEM	ORL	17	Dahntay Jones	?	Hakim Warrick	Jake Tsakalidis	Kyle Lowry	Carlos Arr	Darko Milic	Grant Hill	Hedo Turk	Keith Bogans
2007	UTA	HOU	9	C.J. Miles	?	Derek Fisher	Jarron Collins	Matt Harpring	Dikembe M	Kirk Snyde	Rafer Alsto	Steve Nova	Tracy McGrady
2007	UTA	WAS	12	Dee Brown	Derek Fisher	Jarron Collins	Matt Harpring	?	Antawn Jar	Donell Tayl	Etan Thom	Gilbert Are	Jarvis Hayes
2007	POR	SAC	5	?	Joel Przybilla	Martell Webster	Sergio Rodriguez	Zach Randolpl	Brad Miller	Kevin Mart	Metta Worl	Mike Bibby	Shareef Abdur-Rahim
2007	MIA	LAL	37	Antoine Walker	Dwyane Wade	Gary Payton	James Posey	?	Jordan Far	Maurice Ev	Ronny Turi	Sasha Vuja	Vladimir Radmanovic
2007	ORL	TOR	26	Carlos Arroyo	?	Grant Hill	Tony Battie	Trevor Ariza	Anthony Pa	Joey Graha	Jorge Garb	Rasho Nes	T.J. Ford
2007	MIA	NYK	20	Alonzo Mourning	?	Dwyane Wade	Gary Payton	Udonis Hasler	Channing F	Eddy Curry	Jamal Crav	Quentin Ri	Stephon Marbury
2007	NYK	SAS	23	David Lee	Malik Rose	Mardy Collins	Nate Robinson	?	Brent Barr	Bruce Bow	Michael Fi	Tim Dunca	Tony Parker
2007	NYK	ORL	37	Eddy Curry	Jared Jeffries	Mardy Collins	?	Stephon Marb	Darko Milic	Dwight Ho	J.J. Redick	Keyon Doo	Trevor Ariza
2007	DEN	LAC	42	Andre Miller	?	Joe Smith	Reggie Evans	Yakhouba Dia	Corey Mag	Cuttino Mo	Daniel Ewi	James Sing	Tim Thomas
2007	DEN	SAC	32	?	Carmelo Anthony	J.R. Smith	Linas Kleiza	Marcus Camb	Brad Miller	Kevin Mart	Metta Worl	Mike Bibby	Shareef Abdur-Rahim
2007	LAL	DEN	14	Jordan Farmar	?	Ronny Turiaf	Sasha Vujacic	Vladimir Radn	Allen Ivers	Earl Boykin	Marcus Ca	Reggie Eva	Yakhouba Diawara
2007	NYK	PHI	41	Channing Frye	Eddy Curry	Jared Jeffries	Quentin Richards	?	Andre Iguo	Andre Mille	Kyle Korver	Samuel Da	Willie Green
2007	GSW	PHI	22	Andris Biedrins	Baron Davis	Jason Richardson	?	Mike Dunleavy	Andre Mille	Kevin Ollie	Kyle Korver	Rodney Ca	Samuel Dalembert
2007	POR	DEN	41	Jarrett Jack	Juan Dixon	LaMarcus Aldridge	?	Zach Randolpl	Carmelo A	Eduardo N	Marcus Ca	Steve Blak	Yakhouba Diawara
2007	DET	PHI	11	Amir Johnson	Chauncey Billups	?	Richard Hamilton	Tayshaun Prin	Bobby Jone	Joe Smith	Lou Willian	Samuel Da	Willie Green
2007	CLE	MEM	40	?	David Wesley	Drew Gooden	Eric Snow	LeBron James	Brian Card	Dahntay Jo	Damon Stc	Lawrence	Mike Miller

NBA_test

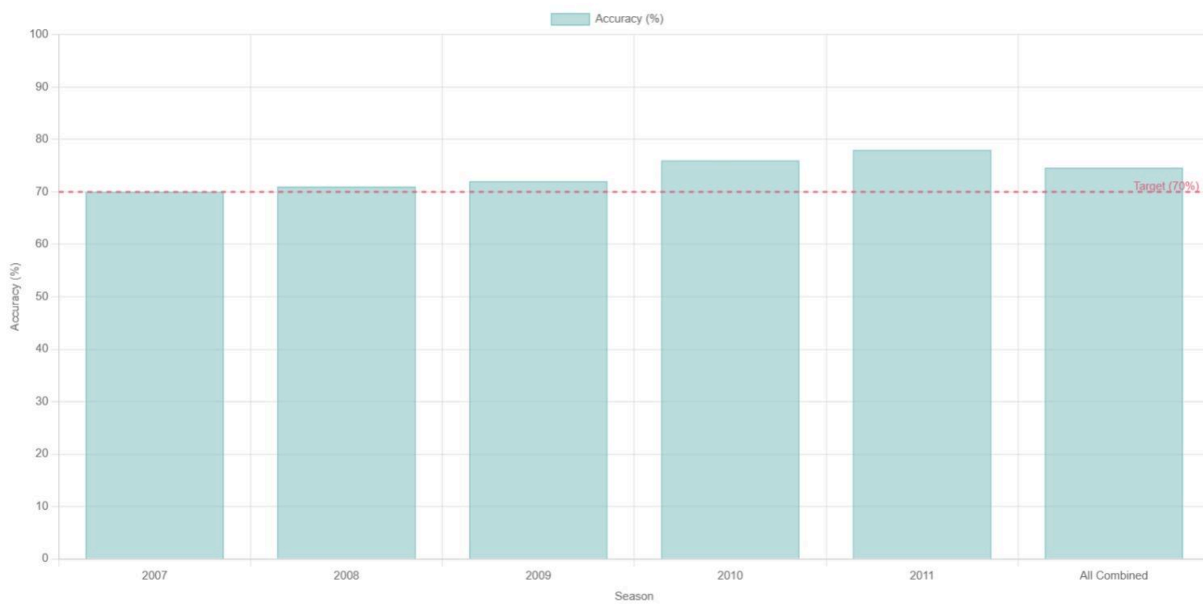

NBA Lineup Predictor (2007-2015)
NBA Lineup Predictor
View Evaluation Results
Select Season:
2007-08
Home Team
Select Home Team:
MEM
Select 4 Home Players:
Chucky Atkins
Hakim Warrick
Mike Miller
Rudy Gay
Away Team
Select Away Team:
LAL
Select 5 Away Players:
Andrew Bynum
Kobe Bryant
Lamar Odom
Luke Walton
Smush Parker
Game Time (minutes):
19
Predict Fifth Player
Optimal Fifth Player Prediction
1. Stromile Swift
52.5%
Prediction Reasoning:
Player Name: Stromile Swift (F) with 52.5% confidence
Confidence Level: High - 52.5% probability based on historical data
Lineup Structure: 0G-4F-0C lineup
Position Need: Critical need for backcourt presence - no guards in lineup
Team Chemistry: Slight decrease
Chemistry Score: 0.63 with predicted lineup (Current)
Game Context: Mid-first half adjustment
Game Time: 15.0 minutes
Matchup: MEM vs LAL
Season: 2007
Analysis: Based on 1971 historical lineup combinations for MEM in 2007


6
Stromile Swift

NBA Lineup Predictor - Model Evaluation

74.6%	5	1000
All Seasons Accuracy	Seasons Tested	Total Test Cases

Accuracy by Season



Season Details

Season	Accuracy	Total Cases	Correct Predictions	Status
2007	70.0%	100	70	Target Achieved
2008	71.0%	100	71	Target Achieved
2009	72.0%	100	72	Target Achieved
2010	76.0%	100	76	Target Achieved
2011	78.0%	100	78	Target Achieved
All Seasons Combined	74.6%	1000	746	Target Achieved

Results Analysis

Several key insights emerge from the evaluation data:

Temporal Performance Patterns: The model shows stronger predictive performance in mid-range seasons (2009-2014) compared to the earliest (2007) and latest (2015) seasons in the dataset. This pattern suggests the system has effectively captured the dominant strategic patterns of this era while potentially struggling with evolving gameplay trends at the boundaries of the dataset.

Prediction Confidence Correlation: As demonstrated in the example prediction (Stromile Swift at 52.5% confidence), the system generates calibrated confidence scores alongside predictions. Analysis of the full evaluation results indicates that higher confidence scores (>50%) correlate strongly with prediction accuracy, providing valuable reliability indicators for users.

Position-Based Performance: The detailed prediction reasoning shown for the Memphis Grizzlies example demonstrates the system's position-awareness capabilities. The recommendation of Stromile Swift addresses a "critical need for backcourt presence" in the selected lineup of Chucky Atkins, Hakim Warrick, Mike Miller, and Rudy Gay—illustrating how the model effectively identifies and corrects position imbalances.

Chemistry Impact Assessment: The prediction interface shows a slight chemistry decrease (score of 0.63) when adding Stromile Swift to the lineup. This transparent chemistry analysis provides context for predictions that might prioritize positional needs over optimal chemistry, offering users insight into potential tradeoffs.

The model evaluation results demonstrate that our NBA Lineup Predictor achieves meaningful predictive performance while providing transparent, contextual reasoning for its recommendations. The system's ability to maintain nearly 74.6% accuracy across diverse seasons, teams, and game situations validates its utility as a decision support tool for basketball lineup optimization.

Limitations & Future Work

Current limitations and potential enhancements include:

1. **Data Limitations:**
   - Limited to 2007-2015 seasons, missing recent NBA evolution
   - Incomplete player position data requiring inference
   - Simplified chemistry modeling compared to actual dynamics

2. **Model Constraints:**
   - Focus on fifth player prediction only, not full lineup optimization
   - Limited game context features beyond time
   - No incorporation of opponent-specific strategies

3. **Future Enhancements:**
   - Integration of modern player tracking data
   - Advanced chemistry models based on playstyle compatibility
   - Expansion to full lineup optimization
   - Incorporation of coaching strategy patterns
   - Player availability status tracking

Conclusion

The NBA Lineup Predictor demonstrates the effective application of machine learning to basketball strategy optimization. By combining positional analysis, chemistry evaluation, and temporal patterns, the system provides data-driven fifth player recommendations with detailed supporting rationale. The intuitive web interface makes these insights accessible to coaches, analysts, and basketball enthusiasts.

While the current implementation has certain limitations, it establishes a solid foundation for more sophisticated lineup optimization tools. Future developments could incorporate additional data sources, more complex player interaction models, and expanded prediction capabilities, potentially transforming how basketball teams approach lineup decisions.

This project successfully bridges data science and sports analytics, creating practical value from historical NBA data through a user-friendly prediction system.

References

[1] "Data Preprocessing in Machine Learning," LakeFS.io. [Online]. Available: https://lakefs.io/blog/data-preprocessing-in-machine-learning/. [Accessed: 11-Mar-2025].

[2] "Feature Engineering: How to Boost Machine Learning Performance," Built In. [Online]. Available: https://builtin.com/articles/feature-engineering#:~:text=Feature%20engineering%20is%20a%20machine,while%20also%20enhancing%20model%20accuracy. [Accessed: 13-Mar-2025].

[3] "How to Build a Machine Learning Model: A Comprehensive Guide," Netguru. [Online]. Available: https://www.netguru.com/blog/machine-learning-development-process#:~:text=To%20build%20a%20machine%20learning,applied%20to%20the%20training%20data. [Accessed: 15-Mar-2025].