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Outline

What is a Smart Parking System?

A technology-driven solution to optimize parking space usage and reduce parking-related challenges.

Combines real-time data, IoT sensors, and software applications to streamline parking management.

User Problems and Smart Parking Solutions

Environmental and Traffic Concerns

Reduces search time, cutting down on traffic and emissions.

Difficulty Finding Parking

Shows real-time available spots, guiding drivers directly to them.

Unexpected Parking Costs

Uses dynamic pricing so drivers can see and plan for costs ahead.

Inconvenient Payment Methods

Offers easy digital payment options via mobile apps.

Limited Parking During Peak Times

Manages spaces better with dynamic pricing and real-time updates.

Poor Navigation within Parking facilities

Provides guided navigation and parking reminders.

Key Beneficiaries

Drivers

Reduce stress and time searching for parking in urban areas, especially during special events.

Parking Operators

Optimize revenue, manage resources, and enhance customer satisfaction.

City Authorities

Reduce traffic congestion and emissions, improve urban planning.

Local Businesses

Increase foot traffic due to accessible parking..

Data Overview

4 months of data analyzed

13.4 million parking slots

57 Roads

- Each road has **at least one parking space**.
- The average parking slots per road is about **11.**
- Half the roads have **4 or fewer** available spaces.

Data focuses on

6:00 AM - 9:00 PM

Peak Hours

- Weekdays, especially **midweek**.
- **10:00 AM - 3:00 PM**
- **6:00 PM - 9:00 PM**

Environment

- Mild temperatures (**average 16°C**).
- Average precipitation: **0.10 mm.**
- Winds: Moderate (**12.75 km/h**).
- Parking demand decreases during bad weather (**<7°C or >30°C**).

- **Max capacity** and **availability** have a strong positive correlation (0.95)
- Feature Importance: **Max capacity, occupied spaces**, and **restaurants** are critical factors.

Behavioral Trends

- Parking occupancy increases significantly when the weather is good.
- Areas near homes, schools, and restaurants tend to have higher parking demand.
- Only 25% of the segments having public transport options (restricts park-and-ride opportunities.)

Data Issues and Challenges

Missing Values

Commercial Variable

Requires imputation (mean, median, or interpolation)

Outliers

Transportation (17.54%)
Precipitation (22.73%)

Capping or replacing to reduce distortion.

Logical Inconsistencies

Occupied + Available = Max Capacity
1,353 negative values in Available

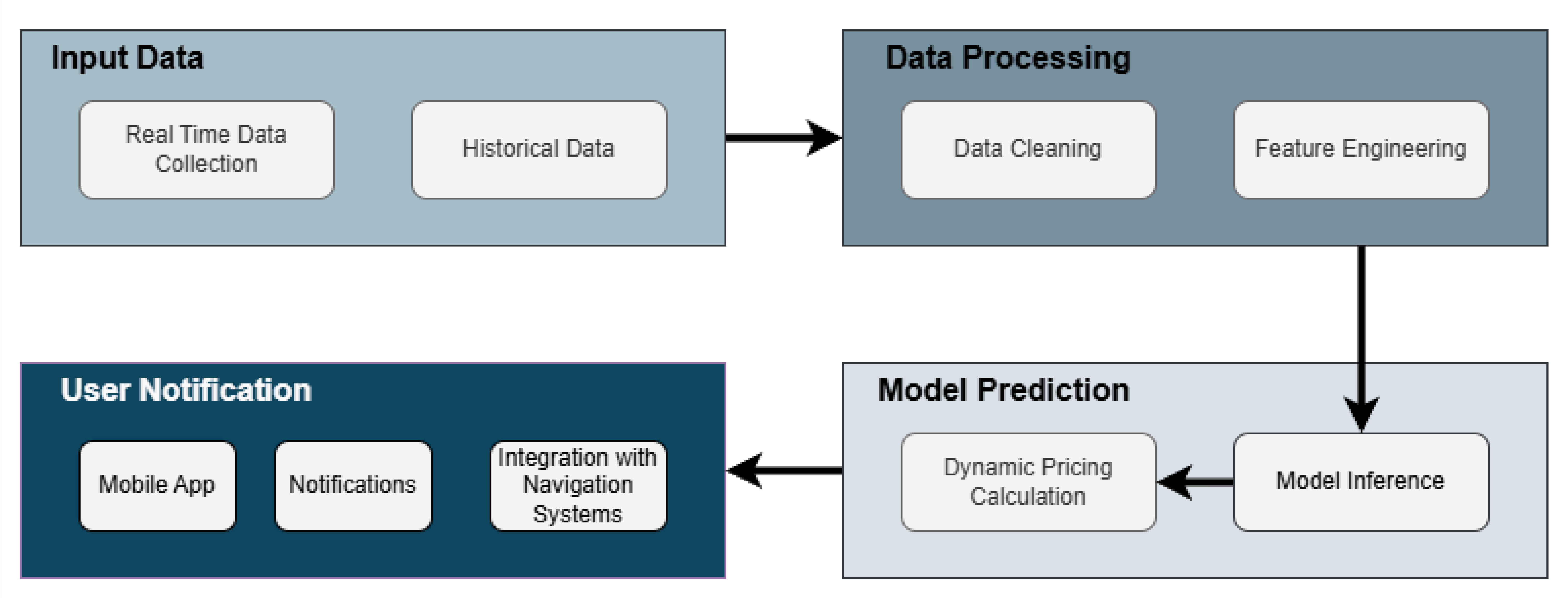
Replaced with zero.

Incorrect Values

Temperature Variable: Contains an invalid value of -999

Replaced with average or zero.

System Workflow



Modeling and Performance Evaluation

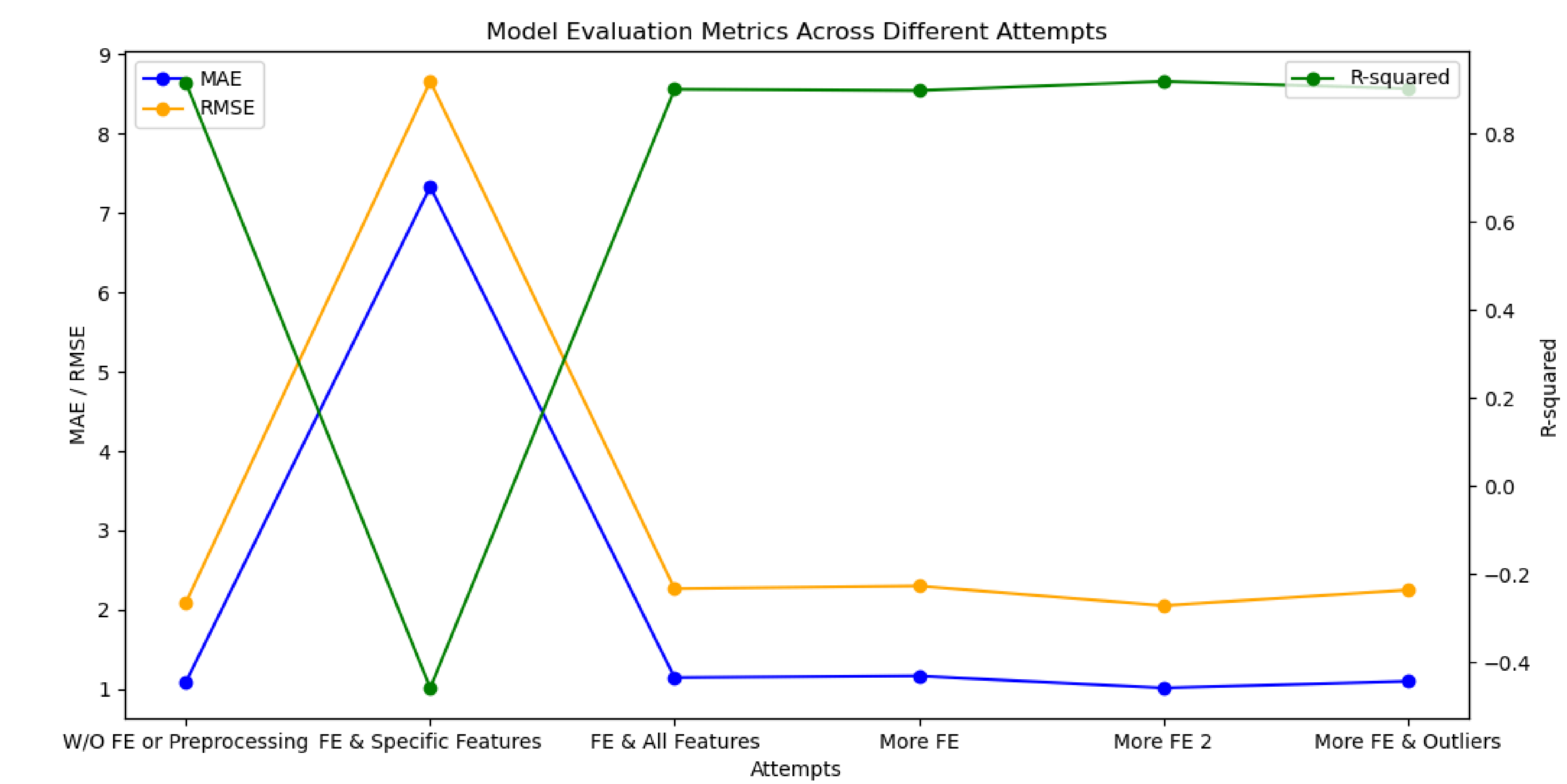
Modeling Approach

Random Forest Regressor
Robust to outliers, handles mixed data types, and provides feature importance.

Gradient Boosting
High accuracy but slower training

XGBoost
Efficient but requires fine-tuning to avoid overfitting.

Linear Regression
Fast and interpretable but limited in capturing non-linear patterns.



Random Forest Regressor

Performance Metrics

- **Mean Absolute Error (MAE)**: 1.04 (average error: ~1 spot).
- **Root Mean Squared Error (RMSE)**: 2.11.
- **R^2**: 0.91 (explains 91% of variance).

Future Improvements

Hyperparameter Tuning

- Use grid search or random search to optimize parameters (max depth, min sample split).
- Avoid overfitting through careful optimization

Advanced Algorithms

Gradient Boosting (XGBoost, LightGBM), neural networks, or ensemble models.

Feature Engineering

Create interaction terms or leverage seasonal trends for better insights.

Additional Data Sources

Event Data
Capture increased parking demand during special events.

Traffic Volume
Real-time density or flow helps dynamically adjust predictions.

Nearby Parking Availability
Predict overflow patterns.

Weather Details
actors like humidity and visibility impact short-term behavior.

Public Transport Schedules
Useful for park-and-ride demand trends.

EV Charging Stations

KPIs

Category	KPI	Description
Prediction accuracy	Mean Absolute Error (MAE) , Root Mean Squared Error (RMSE), R-squared (R^2)	Measure the model performance
System performance	Latency	The time taken to generate predictions and deliver them to users.
	Uptime	The percentage of time the system is operational and available to users.
User engagement	User retention rate	The percentage of users who continue to use the app over time.
	User satisfaction	Measured through user feedback and ratings.
	Notification click through rate	The percentage of users who click on notifications about parking availability and pricing.
Revenue and utilization	Revenue from dynamic pricing	The total revenue generated from dynamically priced parking spots.
	Occupancy rate	The percentage of parking spots that are occupied at different times.
	Peak time utilization	The effectiveness of the model in managing parking during peak hours.
Operational efficiency	Cost of operation	The total cost incurred in maintaining the smart parking system.
	Resource utilization	The efficiency in the use of computational andhuman resources to manage the system.

Recommendations

Implement Dynamic Pricing

- Increase prices during peak hours
- Lower prices during off-peak times and weekends to encourage usage.
- Offer discounts during bad weather.
- Adjust prices for events (18:00–21:00) to capitalize on demand spikes

Improve User Experience

- Enable multiple payment methods (mobile apps, contactless payments).
- Provide live availability updates and navigation assistance via apps or websites.
- Actively collect and analyze user feedback to improve parking services.

Maintain Operational Excellence

- Ensure proper management of the parking system during peak times to enhance customer satisfaction.
- Develop a robust monitoring and maintenance plan for IoT sensors and infrastructure.

Invest in Infrastructure

- Develop more off-street parking facilities in high-demand areas with limited current infrastructure.
- Explore integrating EV charging stations to cater to electric vehicle users.

Expand Data Sources

- Incorporate real-time traffic and public transport data for enhanced demand prediction.
- Utilize event and social data to anticipate parking demand fluctuations.

Promote Sustainability

- Encourage eco-friendly parking with discounted rates for electric and low-emission vehicles.
- Reduce emissions by minimizing search times through efficient parking allocation.

Conclusion

- Smart parking systems solve real problems like finding spots, easy payments, and reducing congestion.
- Dynamic pricing and real-time data make parking more efficient and profitable.
- Users enjoy smoother experiences, and cities benefit from less traffic and emissions.

Future Developments

- Add real-time data like traffic and events for better predictions.
- Expand parking with EV-friendly options to support the future.
- Keep improving with smarter algorithms and new tech.

Thank you