ParkFlow: Intelligent Dispersal for Mitigating Parking Shortages with Multi-Granular Spatial-Temporal Analysis

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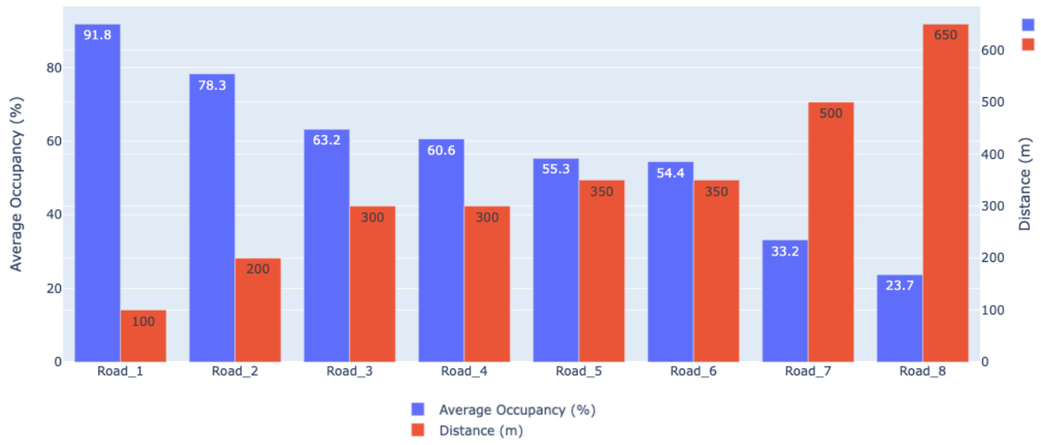
Motivation

Our motivation is to address the challenges associated with parking near popular destinations by introducing innovative solutions "ParkFlow", aiming to improve parking habits, availability, and the overall urban functionality in Taiwan and inspire similar regions worldwide facing parking-related difficulties.

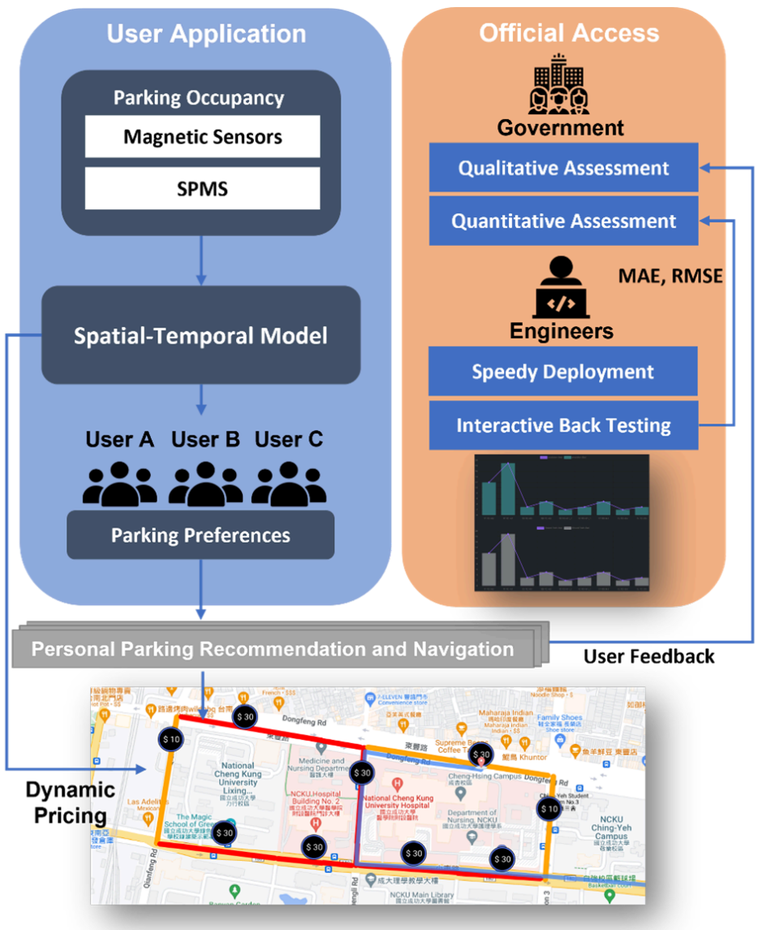


This figure can be explained as that there will be about 70% more parking chances for merely 550 meters away from the croweded space (e.g. NCKU Hospital, Tainan, Taiwan). This issue is widespread around Tainan, Taiwan, for crowded spots.

There are several possible explanations:

1. **Citizens are reluctant to walk more**
2. **Citizens are very rushed**
3. **Crowded areas are severely occupied by long term parking vehicles**
4. **Citizens don't know possible parking spaces nearby**

Proposed Solution



Highlights for Diffrent Using Scenarios

Engineers

- **Interactive back testing functions**
- **Efficient model deployment tools**
- **Consistent matrix for assessment (Quantitative)**
- **Fixed data processing pipeline**

Governments

- **Dynamic Pricing (based on Spatial-Temporal model)**
- **Feedback Analysis Mechanism (Qualitative)**
- **Robust and transparent platform**

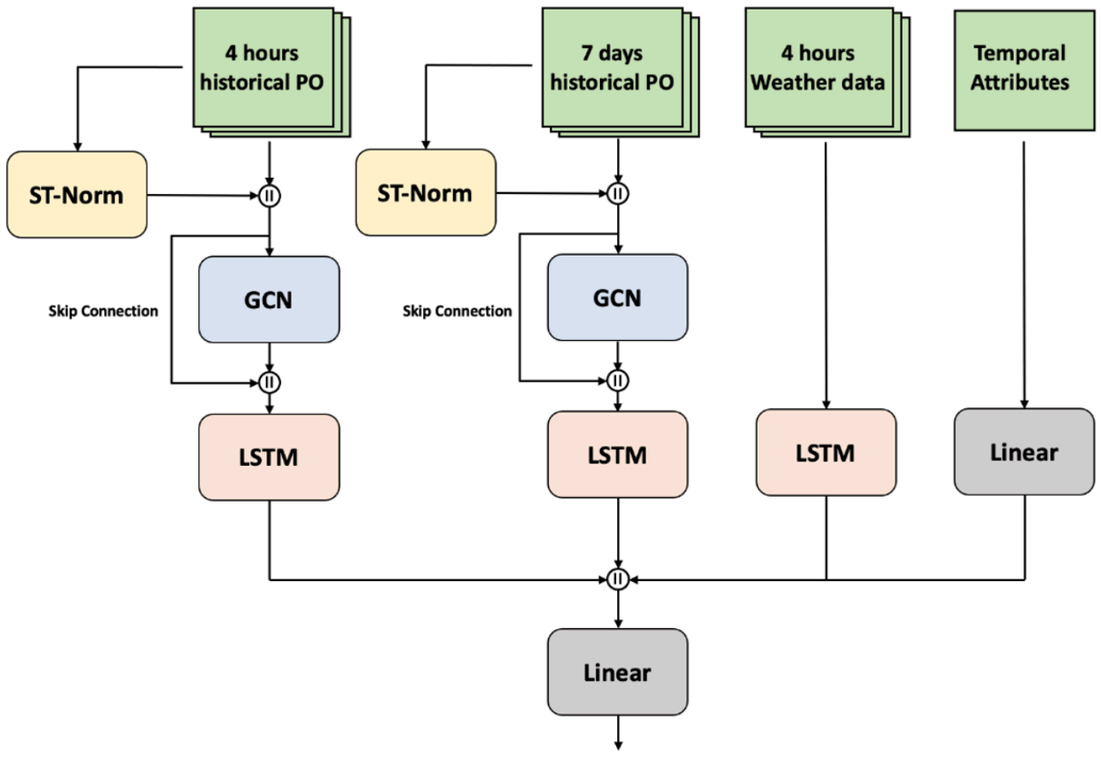
Users

- **Navigation to the recommended road segment**
- **Personal Parking Recommendation**
  - **Optimal prizing suggestion**
  - **Long/Short term parking**
  - **Minimizing walking distances**
  - **Disabled parking spaces**

Contributions

1. **For "Citizens": (1) More accurate and personalized recommendations (2) Far more user friendly and intuitive**
2. **For "Governments": (1) Outdated parking application are replaced (2) Dynamic pricing to disperse long term parking (3) Mitigate traffic chaos**
3. **For "Engineers": (1) Easier to cooperate with the Government (2) Quiker model deployment (3) Easier to back test and analyze (4) Tuning models from user feedbacks**

Model



Our goal is not to compete with the SOTA models, instead we utilized several methods to proof the possiblities and advantage of our parking recommendation system. Furthermore, these models are deployed on our system as strong baselines to inspire engineers for further fine-tuning and improvements. The best model depicted above is named "GCN+LSTM+ST-Norm". Personal parking recommendation and dynamic pricing is based on this best model.

Data Description

Smart City hardwares in Tainan "Smart Parking Meter System (SPMS)" and magnetic sensors incoporates real time data flow with our parkflow system. Spatial temporal models deployed on our ParkFlow system is based on these real time parking data. Every model (aside from the last 2 rows) at the table utilize these datas:

1. **Previous 4 hours and 7 days parking occupancies (with sampling rate of 10-minute time intervals)**
2. **4 Hours of historical weather data**
3. **Temporal attributes (time of date, day of the week, and day of the year)**

Experiments

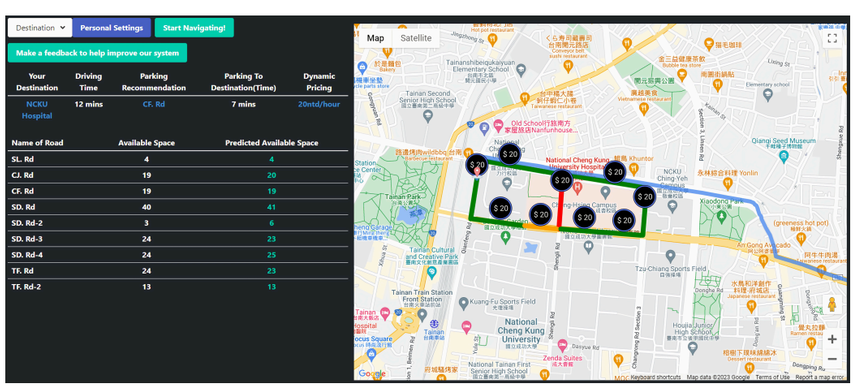
	30 min		60 min		90 min	
Models	MAE	RMSE	MAE	RMSE	MAE	RMSE
GCN+LSTM+ST-Norm	<u>1.6650</u>	<u>2.3668</u>	**2.0165**	**2.8680**	**2.2133**	**3.1494**
GCN+LSTM	1.6845	2.3929	<u>2.0643</u>	<u>2.9176</u>	2.2880	<u>3.2178</u>
XGBoost	**1.6590**	**2.3605**	2.0721	2.9531	2.2724	3.2415
LSTM	1.7669	2.5022	2.0721	2.9587	<u>2.2451</u>	3.2222
LASSO	2.2042	3.1726	2.6466	3.7283	2.8524	3.9882
Latest Observation	2.1159	3.2585	3.2690	5.0367	4.1353	6.2587
Historical Average	4.3112	6.3381	4.3112	6.3381	4.3112	6.3381

The taks is to predict "parking occupancy" for each road segments in future intervals of 30, 60, and 90 minutes. MAE and RMSE are selected as evaluation matrix. In our experiments, data are collected from March 1, 2020, to August 31, 2022, 3-fold cross-validation are applied, specifically focusing on 9 road segments located around the crowded NCKU Hospital, Tainan.

- **"Latest Observation": predicting by using the latest historical parking occupancy**
- **"Historical Average": predicting by using the average of historical parking occupancy (previous 4 hours)**

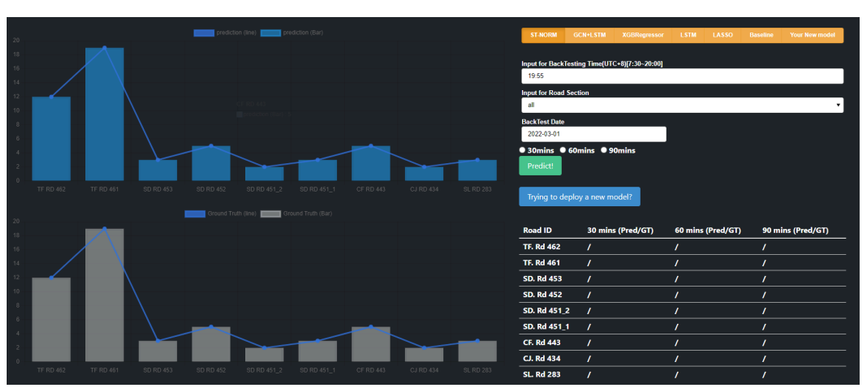
Inferfaces and Functions

Personal Parking Recommendation & Navigation



ParkFlow integrates personalized parking recommendations into navigation to help users find parking more easily, addressing poor parking habits, reducing traffic chaos, and promoting a balanced parking environment by considering user preferences and inclusivity needs.

Back Testing & Deployment Tools



ParkFlow provides a unified platform for efficient model design, testing, and deployment, utilizing abundant parking occupancy data. This fosters collaboration and enables continuous improvement of recommendations and performance.

User Feedback & Analysis

ParkFlow enhances user experience by incorporating a feedback mechanism, allowing users to report thoughts on parking recommendations. This helps evaluate model performance, understand user opinions, and informs the government's traffic policies for more effective parking solutions.