THE PREDICTION OF PARKING AVAILABILITY

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INTRODUCTION

Nowadays heavy traffic congestion is noticeable in urban areas, especially in well-developed cities with growing number of vehicles. It is a well-known fact that, this scenario resulted from drivers looking for available parking spaces. In order to address this issue, many studies have been conducted recently to predict parking availability which could be a guide to drivers, thus saving time, cost and energy consumption; and reducing air pollution in cities.

A 2-Step Approach to Improve Data-driven Parking Availability Predictions study used real dataset of parking spaces from SFPark project which was gathered by San Francisco Municipal Transportation Agency in 2013. This paper focused to overcome problem like reducing contribution of noisy data from stationary or mobile sensors in parking availability predictions for Parking Guidance and Information (PGI) systems. The motivations of this paper are difficulty in training generalized model using noisy data and issues faced in evaluating the accuracy of prediction model tested on noisy data (Bock, Di Martino, & Origlia, 2017).

Parking Availability Prediction with Long Short-Term Memory Model research employed parking events data collected from more than in-ground 3000 sensors which were placed in each on-street parking slot around Melbourne Central Business District area. The focus point of this paper is to introduce Recurrent Neural Networks (RNNs) as part of parking availability prediction model as RNNs have been used extensively in sequential-data and time-dependent based research areas like electricity consumption, text generation, power forecasting, POS tagging and dynamic mortality risk predictions (Shao et al., 2019).

Predicting Available Parking Slots on Critical and Regular Services by Exploiting a Range of Open Data proposed the best prediction technique among 4 prediction models which exploited open data in the context of Sii-Mobility (national smart city research project of Italian Ministry of Research for terrestrial mobility and transport) and Km4City infrastructure in Florence, Italy. This paper focused on prediction of parking availability in parking garages with gates by taking into account a number of factors like baseline features of free slot data, weather features and traffic sensors features. The motivation of this study is to build a strong prediction model in regard to critical cases like the number of free slots reaching zero and missing data in the stream (Badii, Nesi, & Paoli, 2018).

PARKING AVAILABILITY PREDICTION MODEL

A 2-Step Approach to Improve Data-driven Parking Availability Predictions paper proposed a 2-step approach to first extract underlying trends from raw data and later made use of the obtained curves to train and test regression model to predict parking availability. In the first step, *Support Vector Regression (SVR)* the adaptation of Support Vector Machine (SVM) to regression issues and *Genetic Algorithm (GA)* were deployed to extract the trend model. It is recognized that in binary classification issues, SVM looks for hyperplane separating the elements of two classes with the largest margin while SVR is capable of emulating the training set points with an error on each point lower than a constant. Meanwhile, GA was optimized to search for SVR hyper-parameters with the aim of selecting simplest model with minimum number of support vectors to obtain smooth curves as part of first step. With the fitting models obtained in step one, SVR is then used in second step to predict parking availability without the risks modelled by noisy data.

Parking Availability Prediction with Long Short-Term Memory Model paper proposed parking prediction

framework which consists of two modules namely occupancy prediction module and duration estimation module. The research found that occupancy rates in different regions have similar trend but the value of each region is significantly different even at the same time. *K-means clustering* algorithm aims to partition samples into k clusters in which each sample belonging to the cluster with the highest similarity. Hence, K-means clustering was applied to spatio-temporal parking data to group around 3000 on-street parking spaces into 30 regions with similar patterns to boost accuracy of the model. *Long Short-Term Memory (LTSM)*, a variant of RNNs with the capability of learning long-term dependencies was then implemented for occupancy prediction of each group of parking spaces. On the other hand, the research found that probability density of duration time of different regions has similar curves which rules out the need to apply use clustering method in duration estimation module. Nonlinear least square was used to estimate the probability density function of duration time with the corresponding *regression* model based on three factors which are the day in a week, occupancy rate and time in a day.

Predicting Available Parking Slots on Critical and Regular Services by Exploiting a Range of Open Data paper made comparison between a number of techniques like *Bayesian Regularized Artificial Neural Networks (BRANNs)*, *Support Vector Regression (SVR)*, *Auto-Regressive Integrated Moving Average (ARIMA)* and *Recurrent Neural Networks (RNNs)* and then finally suggested *BRANNs* as the most efficient model for parking prediction. Artificial Neural Network (ANN) a very popular supervised learning technique which have been used as powerful non-linear regression technique when it was first introduced. A good generalization cannot be expected out of ANN as it has the tendency to overfit by training the Neural Network to fit the noise trend. Nevertheless, *BRANNs* avoids overfitting of ANNs by integrating Bayes' modelling into

regularization structure and pushing redundant weights towards zero. This makes BRANNs more robust, parsimonious, and efficient than ANNs with more significant network weights in modelling qualifies as one of the prediction approaches in this study. *SVR* is a nonlinear generalization algorithm with the capability of learning machines to gain performances in regression and time series prediction. Hence, SVR with linear kernel has been implemented as second parking predictive technique in this paper. SVR was developed from the computation of linear regression function to given dataset in high dimensional feature space where the input data are mapped via a nonlinear function. SVR minimizes the generalization error bound, the combined values of training error and regularization term governing density of the hypothesis space. *ARIMA* approach is another prediction technique used in this paper. ARIMA approach consists of two parts which are Auto-Regressive (AR) and Moving Average (MA). AR provides ground to the prediction while MA models errors committed in preceding time instants of prediction and further improves the model. RNNs, a Feed-Forward Neural Network with a recurrent loop are regarded as well-known prediction model to solve problems involving time sequences of events and ordered data. RNNs composes of hidden states and outputs which operate on a sequence of inputs. Though training RNNs could be challenging, it has been taken into account as another model in parking prediction in this research due to its simplicity and strength in prediction.

COMPARISON AND CONTRAST

All three researches were conducted based on real-world parking dataset which had been collected by respective organizations. Contrasts between the studies can be observed in the following table. Papers numbered 1: A 2-Step Approach to Improve Data-driven Parking Availability Predictions; 2: Parking Availability Prediction with Long Short-Term Memory Model; 3: Predicting Available Parking

Slots on Critical and Regular Services by Exploiting a Range of Open Data

Papers	1	2	3
Types of parking facilities			
Street Parking	*	*	
Parking Garages with Gates			*
Machine Learning Techniques Used			
Support Vector Regression (SVR)	*		*
Genetic Algorithm (GA)	*		
K-means Clustering		*	
Auto-Regressive Integrated Moving Average (ARIMA)			*
Recurrent Neural Networks (RNNs) (variants inclusive)		*	*
Bayesian Regularized Artificial Neural Networks (BRANNs)			*
Non-linear Regression		*	
Model Evaluation Metrics			
Root Mean Square Error (RMSE)	*	*	
Mean Absolute Error (MAE)		*	
Mean Absolute Percentage Error (MAPE)		*	
Root Relative Squared Error (RRSE)		*	
Mean Absolute Scaled Error (MASE)			*

DISCUSSION

It is clear that Support Vector Regression (SVR) and Recurrent Neutral Networks (RNNs) techniques are commonly used in parking availability prediction models. A parking availability prediction model with boosted accuracy could be produced when more than one machine learning algorithms are combined in the implementation of the prediction model as applied in *A 2-Step Approach to Improve Data-driven Parking Availability Predictions* and *Parking Availability Prediction with Long Short-Term Memory Model.* Besides that, the robustness of model could be increased by taking multiple factors into consideration during model building. Those factors are weather features like temperature, humidity and rainfall; traffic sensor features like vehicle speed, flow time and concentration; and time factors like day in a week and time in a day. Although, generally RMSE is adopted in evaluation of parking availability prediction model, it is necessary to choose and tailor appropriate evaluation metrics.

REFERENCES

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