Detecting Predominance of on-Street Parking Payment Schemes by Means of Linear Regression

Amtul Waheed, P.Venkata Krishna

Abstract—On street parking is one of the important and crucial components of urban traffic and transportation system. Allocation of parking space on street is major reason for traffic congestion. Optimizing traffic congestion and facilitating on street parking is a long stand issue. According to urban environment it is expected that car drivers prefers parking space based on road conditions, speed limit and surrounding activities and availability of parking space. The other major components to be ponder while searching parking space is payment method used while parking the car. This paper investigates car driver's behaviors in selecting parking payment schemas, visualized data as well predicted via machine learning technique of linear regression analysis on the open data set of On-street Car Parking Meters with Location of City of Melbourne's in the Australian.

Keywords—smart parking, on-street parking, parking meters

I. INTRODUCTION

With the development in field of motorization and urbanization intensification in the stream of transportation has increased subsequently saturating the road networks due to limitations in financial, physical and ecological resources. It is very crucial to manage efficiently transport system as to avoid further traffics congestions, accidents and shortage of parking space particularly in urban areas [1].

On street parking is much cost effective and easily available across the city, it is preferred above central garage parking. Also people driving in urban areas always like to find parking near to their destination though it is a very challenging task as searching for vacant parking space driver has to drive all over the location this can leads to consummation of time and local traffic jam. According survey conducted 30% of traffic congestion are due to vehicles search for vacant parking spots in busy areas [2].Major component of parking management system is On-street parking [3].

Parking policy strategy can support in reduction of traffic congestion issues and parking search issues by considering drivers needs and decisions while scheming parking policy [4]. Thus it is very important to consider factors related to car drivers on street parking demands and requirements.Many researches have been conducted on different features of intelligent parking systems such as system development, occupancy detection and shared service design [5].Some research works rely on reservation-based solution designed for controlled off-street parking facilities which is based on parking assignment algorithms. However, these parking assignment algorithms are reservation-based Solutions which do not operate for on-street parking, since there is no mechanism to enforce reservation. [6].

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Metropolitans such as San Francisco and Melbourne are deployed with on street smart parking meters to sense the occupancy status of the spots and provide real time availability information via network infrastructure.

This paper is organized as follows. Section 2 discusses technology deployed in Smart parking systems. Framework of on street smart parking system is provided in section 3. Section 4 represents communication/interaction in on street smart parking system. Section 5 presents the methodology for conducting the research. Sections 6 demonstrate experimental setup. Analysis and interpretation of the model output is explained in detail in section 7. While conclusions are presented in section 8.

II. TECHNOLOGY DEPLOYED

A. Smart parking sensors:

Real time parking system depends on the information collected by sensors about parking availability information sensing on parking places. Typically mobile and stationary these two types of methods are used. Stationary sensor detects vehicle presence or absence and updates the information in a short time as soon as the occupancy status changes [7]. In mobile sensors Vehicles collect data from GPS receiver and ultrasonic sensors and then transmit it over a cellular uplink to the central server. Such a mobile parking sensor system requires much less installation [8]. Table-1 gives a brief overview about types of sensors,

TABLE-I Different types of parking detection sensors

	Sensors	Flexible	Environmental Effect	Small size	Privacy	Installation	Accuracy	Multiple detection
Mobile	Ultrasonic	Yes	Yes	Yes	No	Yes	High	Yes
	Laser Rangefinder	Yes	Yes	Yes	No	Yes	High	Yes
	Smart Phone	Yes	Yes	Yes	yes	No	NO	Yes
	Camera	Yes	Yes	Yes	Yes	Yes	Low	Yes
Stationary	Active/Passive infrared	Yes	Yes	Yes	No	Yes	Medium	Yes
	Accelerator	No	Yes	Yes	No	Yes	Low	Yes
	Magnetometer	No	No	Yes	No	Yes	High	Yes
	Ultrasonic	Yes	Yes	Yes	No	Yes	High	Yes
	Camera	Yes	Yes	Yes	Yes	Yes	Medium	Yes
	Acoustic	Yes	Yes	Yes	Yes	Yes	Low	Yes
	Optical	Yes	Yes	Yes	No	Yes	Medium	No
	Inductive Loop	No	No	No	No	Yes	High	No
	Piezoelectric sensor	No	Yes	No	No	Yes	High	Yes
	RFID	Yes	No	Yes	Yes	Yes	High	Yes
	Radar	Yes	Yes	Yes	No	Yes	High	Yes

B. Wireless sensor network (WSN):

After installation of sensors in parking space, next is to form a network for communication. Typically communication methods are of two types short-range and long-range.

- Short Range: it is implemented by wireless sensor network where messages have to be retransmitted several time via relay. Table-2 gives brief Overview of short range WSN technologies.

TABLE-II Overview of short range WSN technologies.

	Bluetooth	Wi-Fi	EnOcean
Frequency	2.4GHz	2.4GHz-5.0GHz	325/868/905/920 MHz
Communication range	10m	Several hundred m	200m
Transmission Speed	1Mbps	11Mbps	125Kbps
Available Channels	**79**	**13-19**	**-**
Transmission Time Limit	No	No	Yes
Modulation Method	Frequency-shift keying (FSK), phase-shift keying (PSK)	Orthogonal frequency division multiplexing (OFDM), Direct sequence spread spectrum (DSSS)	Frequency-shift keying (FSK)

- **Long Range:** The advantage of this technology is it can interact from existing radio access networks and communicate with infrastructure any time anywhere.

Table-III gives brief Overview of long range WSN technologies [9].

TABLE-III Overview of Long range WSN technologies

	SigFox	LoRaWAN	NB-IoT
Frequency	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Unlicensed ISM bands (868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia)	Licensed LTE frequency bands
Communication range	10 km (urban), 40 km (rural)	5 km (urban), 20 km (rural)	1 km (urban), 10 km (rural)
Transmission Speed	100 bps	50 kbps	200 kbps
Bidirectional	Limited / Half-duplex	Yes / Half-duplex	Yes / Half-duplex
Adaptive data rate	No	Yes	No
Modulation Method	binary phase-shift keying (BPSK)	chirp spread spectrum (CSS)	quadrature phase-shift keying(QPSK)

C. Parking meters:

Parking meter is a device used in smart parking system by municipalities to collect money in return of parking space for limited amount of time. On street parking meters are designed to help and establish a connectivity between drivers and parking data by Appling parking policies associated with mobility management and traffic rules to generate revenue from parking lots. There are two types of automated payment parking meters machines single space and multi space as shown in table-IV.

TABLE-IV types of automated payment parking meters machines

Single Space parking meter	Multi Space parking meter
Single space parking meter are for limited on street parking area	Multi-space meter manages several parking meters and can provide more functionalities than single-space one
Payments methods are coin, credit cards, pay by phone app	Payment methods are cash, coins, credits card, pay by phone app, PAY-BY-PLATE.
	

III. FRAMEWORK OF ON STREET SMART PARKING SYSTEM

Framework describes about detailed design of on street car parking system as illustrated in fig.1. Framework is framed in such a way that parking policies meets driver's requirements for suitable parking place. Many factors influences driver while parking the vehicle such as speed limit, distances from destination and surrounding activities. The main objective of this framework is to provide a strong and realistic suggestion regarding car drivers' on-street parking decisions so that parking policies can be framed in accordance with car drivers' behavior, which can reduce number of cars cruising for parking. When drivers are driving towards their destination they enter streets in search of parking opportunities while considering the existing road conditions and parking policies. Based on car drivers' on-street parking choices can be abstracted using the following framework [10].

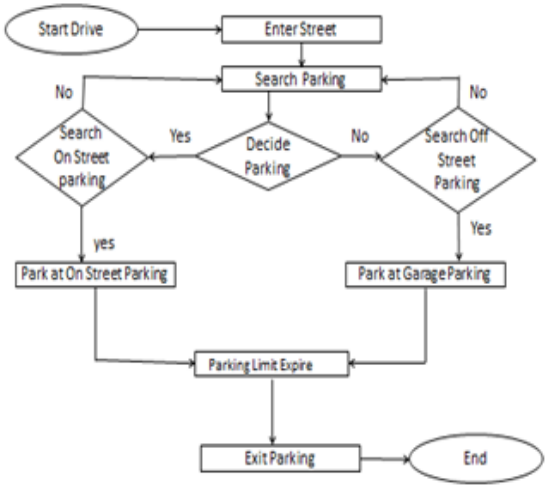

Fig-1 flowchart of on-street parking decisions

IV. COMMUNICATION/INTERACTION IN ON STREET SMART PARKING SYSTEM

Fig-2demonstrates the framework of on-street parking system. Driver uses the parking assistance mobile app to send a parking request from the current area about the destination to the cloud center. The cloud server maintains list of all user requests and updates the real-time parking space status. The server also estimates the users' arrival time and records departure time. Parking meter maintains transaction record of parking payment method and amount depending on the time limitations and stores data in cloud. On street parking systems are mounted with wireless vehicle detector sensors used to gauge the vacant parking space and notify about it to Cloud services.

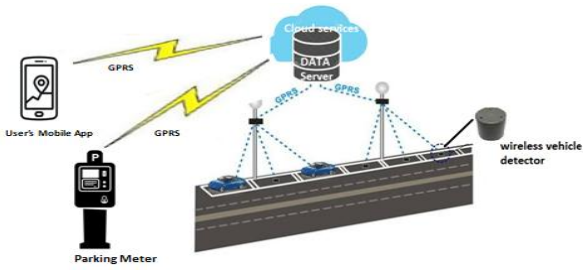

Fig-2 Shows framework of on-street parking system

V. METHODOLOGY

A. *Data Collection:*

City of Melbourne government provided open data with greater transparency and accountability for new innovation and economic opportunities for the Melbourne city. Open data are information that are available for reuse with appropriate open license given to simplify its reuse. All information collected and saved are in machine readable format and made available to general public at the same time protecting privacy and safeguarding sensitive information [11].

- Parking map: Parking maps helps in finding parking space by specifies current vacant position in on street parking bay. It also shows information regarding parking sensors and updates it for every three to five minutes as show in Fig-3.

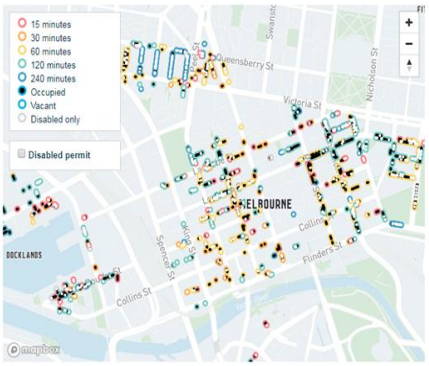

Fig-3 shows the parking positions and its current status

- Parking locations:Parking locations are of two types on street parking and off street parking that is garage parking and commercial car parking.
- Parking fees: The fee structure is based upon inside central city and outside of central city.

- How to pay for parking: There are several techniques available for payment to drivers, including credit card, coins and cashless parking with PayStay
- Pay by phone with PayStay
- Handy hints for using PayStay
- Pay with credit card
- Coins using a parking meter or ticket machine

B. Python visualization:

Data visualization is presentation of data in more understandable means by visualizing the data content to distinguish patterns, trends and correlations. Python offers highly customized and interactive graphing and plotting libraries with extra different features for clarity to presentations.

Matplotlib is one of the most popular plotting libraries which is very easy to use and provides lots of freedom to for visualizing the data. It is a python library which provides high quality figures and interactive environment through the platforms. The Jupyter notebook, the Python and IPython shells, web application servers, and four graphical user interfaces are used in matplotlib.

C. Machine Learning Algorithms-Linear Regression:

Linear regression is one of the machine learning algorithms which is based supervised learning. Independent and dependent variables relation type can be differed and forecast by regression techniques. Linear Regression is a method to demonstrating the relationship between a dependent variable (scalar response or y) and one or more independent variables (explanatory variables or x).By applying regression technique one can finds out a linear relationship between x (input) and y(output). Therefore, it is titled as Linear Regression.

Hypothesis function for Linear Regression:

$$Y = \theta_1 + \theta_2.x \quad (1)$$

x: input training data
y: labels to data (supervised learning)
When training the model – it fits the best line to predict the value of y for a given value of x. The model gets the best regression fit line by finding the best θ_1 and θ_2 values.
θ_1: intercept
θ_2: coefficient of x
Once we find the best θ_1 and θ_2 values, we get the best fit line. So when we are finally using our model for prediction, it will predict the value of y for the input value of x.

VI. EXPERIMENTAL SETUP

A. *Dataset:*

On-street Car Parking Meters with Location are the data sets obtained from City of Melbourne. It provides the location details and information regarding on street car parking meters. It consists of complete information relating to on street parking such as parking meter model type and payment methods supported by parking meters [12].
The data sets are created on august 28, 2017 and are updated on daily basis.It consist of 1,017 Rows and each row is a Parking meter asset. It has 10 columns with the following data as shown in table-V.

TABLE-V describes 10 different columns of datasets.

Column Name	Description
MeterId	The meter name that is displayed on the meter's tariff card.
AssetId	The council's unique id of this asset. This can be used as a reference ID if contacting council to discuss this parking meter
Barcode	The barcode number assigned to this asset.
CreditCard	Information about if this parking meter can accept credit card payment (if enabled).
TapAndGo	Information about if this parking meter has built in Tap 'n go functionality available.
MeterType	The parking meter model.
StreetName	The street name where this parking meter asset is located.
Longitude	longitude of parking space
Latitude	Latitude of parking space
Location	Location of on street parking

B. Python Visualization:

This paper analyses the usage of credit card and tap and go based on meter Id. Figures 4, 5 and 6 shows the visualization of credit card ,tap and go and comparison of credit card and tap and go payment methods, where maximum users are preferring credit card compare to tap and go.

Fig-4 Visualization of usage of credits card method

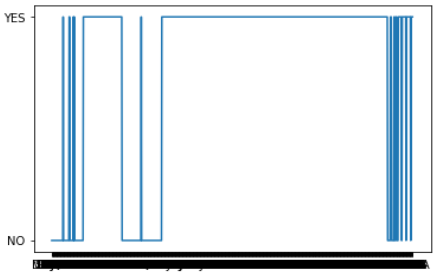

Fig-5 Visualization of usage of tap and go method

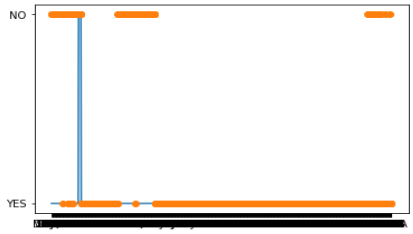

Fig-6 Visualization of comparison of credit card and tap and go methods

C. Predictive Analysis:

a) Linear Regression Analysis on Credit Card:

There is a positive relationship between X that is meterId and Y that is CreditCard as shown in Fig-7. We are predicting Y from X. Linear regression consists of finding the best-fitting straight line through the points which is also regression line. The diagonal line as shown in Figure is the regression line and predicts the usage of credit card for each possible meterId. Vertically each point from the point of the regression line represents the errors of prediction. As points are very near the regression line; its error of prediction is small. By contrast, the points are much higher than the regression line and therefore its error of prediction is large.

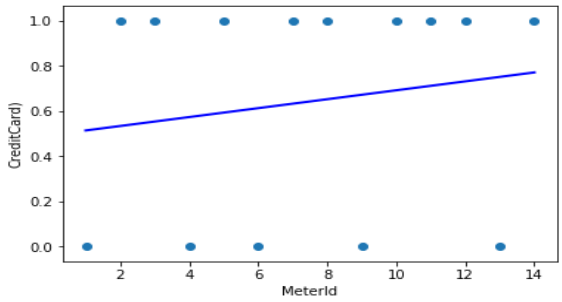

Fig-7 Linear Regression Analysis on Credit Card

b) Linear Regression Analysis on TapAndGO:

The relationship between meterId and TapAndGo that lies on X and Y as shown in Fig-8.We are predicting Y from X. Linear regression consists of finding the best-fitting straight line through the points which is also regression line. The diagonal line as shown in Figure is the regression line and predicts the usage of tapandgo for each possible meterId. Vertically each point from the point of the regression line represents the errors of prediction. As points are very near the regression line; its error of prediction is very less. While the points are much higher than the regression line and therefore its error of prediction is large.

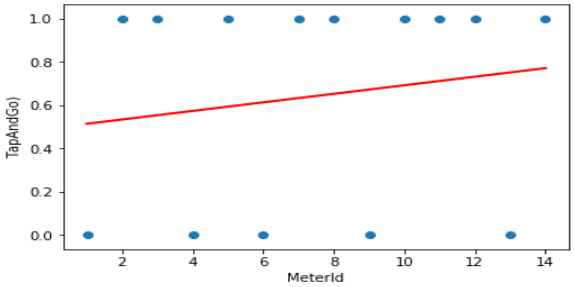

Fig-8Linear Regression Analysis on TapAndGo

D. *Evaluation:*

a) Evaluating the performance of CreditCard method on X-axis:

The model parameters and the performance metrics of the model are given below:
Slope: [0.01978022]
Intercept: 0.4945054945054945
Root mean squared error: 0.2232339089481947
R2 score: 0.02769230769230746

b) Evaluating the performance of TapAndGo method on X-axis:

The model parameters and the performance metrics of the model are given below:
Slope: [[0.00879121]]
Intercept: [0.64835165]
Root means squared error: 0.20282574568288853
R2 score: 0.006153846153846287

VII. ANALYSES AND INTERPRETATION

The aim of this paper is to analyze on street parking payment methods used by drivers while parking car on on-street parking space either by credit card or by using TapAndGO. With the help of available datasets of on-street parking space, comparing and analyzing usage of credit card or tapAndGo methods are done. The datasets are visualized in python which is experimental and further evaluated with the help of machine learning model of linear regression. The results illustrates the two of the used methods are having different analysis. The probability of driver opting for credit card methods are high while compare to TapAndGo methods.

VIII. CONCLUSION

In current situation where roads are overcrowded with traffic and congestions it is very hectic for driver to find parking space of their choice. It is expected that care drivers prefers parking space based on road conditions, speed limit and surrounding activities and availability of parking space.
The other major components to be ponder while searching Parking space is payment method used while parking the car. There are many methods such as credit card, coins, cashless parking, TapAndGO etc.In the paper we are analysing and comparing the two different payment methods for parking the vehicles in on street parking space. We acquired data sets of on street parking meters with location of City of Melbourne. These dataset are analysed and compared in python language data visualization along with linear regression. And experimental result of this analysis is that probability of driver opting for credit card methods are high while compare to TapAndGo methods due to variant reason such as time and preoccupancy of on street parking space near to destination.

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