Reducing CO_2 Emission Using EDA and Weighted Sum Model in Smart Parking System

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***Abstract*—**Emission of Carbon Dioxide (CO_2) has adversely affected the environment. One of the major sources of CO_2 emission is transportation. In the last few decades, the increase in mobility of people using vehicles has enormously increased the emission of CO_2 in the environment. To reduce CO_2 emission, sustainable transportation system is required in which smart parking is one of the important measures that need to be established. To contribute to the issue of reducing the amount of CO_2 emission, this research proposes a smart parking system. A cloud-based solution is provided to the drivers which automatically searches and recommends the most preferred parking slots. To determine preferences of the parking areas, this methodology exploits a number of unique parking features which ultimately results in the selection of a parking that leads to minimum level of CO_2 emission from the current position of the vehicle. To realize the methodology, a scenario-based implementation is considered. During the implementation, a mobile application with GPS signals, vehicles with a number of vehicle features and a list of parking areas with parking features are used by sorting, multi-level filtering, exploratory data analysis (EDA, Analytical Hierarchy Process (AHP)) and weighted sum model (WSM) to rank the parking areas and recommend the drivers with top-k most preferred parking areas. In the EDA process, "2020testcar-2020-03-03", a freely available dataset is used to estimate CO_2 emission of a particular vehicle. To evaluate the system, results of the proposed system are compared with the conventional approach, which reveal that the proposed methodology supersedes the conventional one in reducing the emission of CO_2 into the atmosphere.

***Keywords*—**CO_2 emission, IoT, EDA, Weighted Sum Model, WSM, regression, smart parking system.

I. Introduction

CO_2 is a greenhouse gas that causes trapping of heat in the environment, which leads to the problems of melting ice caps and rising ocean levels, causing flooding [1], [2]. CO_2 emission is linked to human activities such as vehicles on the roads, burning of coal and gases in factories, massive use of fossil fuels, deforestation, waste disposal and mining etc. [1], [3]. In transportation, a typical passenger vehicle emits around 4.6 metric tons of CO_2/year. This amount is with the assumption of average gasoline vehicle that has a fuel economy of about 22.0 miles per gallon and drives around 11,500 miles/year. Every gallon of gasoline burned generates about 8,887 grams of CO_2 [4]. In different parts of the world, countries are importing vehicles, especially personal cars on regular basis without looking into the requirement of parking. This makes cities more polluted with CO_2 emission, because personal cars are one of the main sources of CO2 emission in the transportation.

To reduce CO_2 emission and consequently the global warming, a number of preventive measures can be taken. A few preventive measures include renewable energies, energy & water efficiency, sustainable transportation, sustainable infrastructure, sustainable agriculture & forest management, responsible consumption & recycling [5]. In the sustainable transportation, one of the solutions is smart parking system, which helps in the design of a smart parking management system over the cloud that facilitates drivers in automatically finding a nearest parking area with empty parking slots. This will lead to minimum level of CO_2 emission by the vehicle and will ultimately contribute to the global efforts of reducing CO_2 level in the environment. Therefore, in this research, we are focusing on the design and development of a smart parking system with the use of Internet of Things (IoT). The proposed smart parking system is one of the key fundamentals of smart cities [6], where the infrastructure, including parking slots, is supposed to be smart enough to manage the vehicles. Realization of the concept has been made possible by the recent growth in IoT-based technology and cloud servers management [7]. The applications of smart city are being applied in different countries to improve quality of life and optimize fuel consumption and time to ultimately reduce pollution and CO_2 emission [8]. Smart cities and consequently smart parking solutions will not only help in reducing CO_2 but will also contribute towards increase in revenue, congestion reduction, detection of traffic violations and many more. Searching of parking space in a busy urban area is one of the most important and difficult activities for a driver [9]. In a city, on average, a vehicle moves about 10% of its total travel time, while during the rest of the time, it may be stopped temporarily or parked permanently [10]. Therefore, a smart parking system can best manage the drivers time and solve their problems of parking vehicles in the city with low level of consumption of fuel and emission of CO_2.

In the proposed smart parking system, mobile application with GPS signals, vehicles with a number of vehicle features and a list of parking areas with parking features are used by sorting, multi-level multi-features filtering, EDA and WSM to rank the parking areas and recommend the drivers with top-k parking areas to park their vehicles.

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Key contributions of the study are enlisted below:

- Design of a flexible cloud-based smart parking system framework.
- Identification of a unique set of parking features that not only support the smart parking system in the selection of a car park with minimum level of CO_2 emission but also ensure the selection of a highly rated and secured parking.
- Use of multi-level, multi-features filtering and ranking approach to rank the list of available parking areas.
- Seamless integration of the multi-level multi-features filtering technique, EDA and WSM with mobile application over parking management cloud (cloud server).

The remainder of the paper is organized as follows: Section II presents literature review, Section III illustrates proposed methodology, and Section IV explains experimental results. Section V validates the results and evaluates the system with conventional approach, whereas the study is concluded in Section VI.

II. Literature Review

In literature, several systems have been developed using different techniques and methodologies to assist the vehicles in finding the closest parking slots, both in indoor and outdoor environments. In the indoor parking systems [11], [12], Dijkstra algorithm has been used to find the nearest distanced parking slots in a parking. Similarly, in the outdoor smart parking system [7], genetic algorithm has been applied to find the nearest parking for the users. In [13], Orang Kurang Upaya (OKU) stickers are used by disabled drivers, which implements k-Nearest Neighbors (KNN) algorithm, Otsu binarization and threshold values. These systems are tested in real-world environment. Similarly, in [14], the authors have used KNN algorithm for finding nearest location of parking area. In [15], IoT -based solution is provided for overriding parking hazards and explaining how it helps to minimize emission of greenhouse gases. In this study, IoT enables smart parking system using the system of interconnected Raspberry Pi, distance sensor, Pi camera devices together. These hardware react to one another, collect data and transmit updates to cloud storage. In [16], exploratory analysis, using three stage least-square methods has been used to model the emission of carbon monoxide, CO_2 and hydrocarbon from inspection/maintenance testing data for identifying pollution violators. In China, Logarithmic Mean Divisia Index (LMDI) is used to determine the factors affecting transportation sector CO_2 emissions [17], [18]. In a similar study, Vehicular Ad-hoc Network (VANET) based routing algorithm is proposed for smart parking system which makes use of Updating Block Route Algorithm (UBRA) [19]. Authors of this work claim that their proposed UBRA saves up to 23.6% fuel consumption and 9% CO_2 emission when compared with existing approach. Similarly, in the area of prediction of CO_2 emission in different domains, a number of techniques have been applied and simulated, such as Gauss Optimized Cuckoo Search Algorithm and Wavelet Neural Network Based on STIRPAT model with Ridge Regression in China's Power Generation Industry [20], Geographic Information System (GIS) in geothermal electricity production [21] and three-layer perceptron neural network (3-layerPNN) to learn the characteristics of transportation data and infer the emission of CO_2 [22].

The existing studies are critically reviewed and the following shortcomings are identified: either the existing studies are used for finding nearest parking area or empty slots in the parking areas, or they have been used in the prediction of CO_2 emission level in the domains other than transportation. They lack the use of parking and vehicle features in the ranking and selection of best parking slots for parking the vehicles. Similarly, in the literature, the users' online reviews/sentiments, regarding the parking they used, have not been considered to select preferred parking areas. To address all these issues, a cloud-based smart parking methodology, with multi-level multi-features filtering, EDA and WSM, is proposed. This methodology helps the drivers to automatically find a nearest and suitable parking area with empty parking slots in busy urban areas for parking the vehicles.

III. Proposed Methodology

This study has proposed a smart parking system. Architecture of the proposed cloud-based smart parking system is shown in Fig. 1. Various components of the architecture are explained in the subsequent sections.

A. Mobile Application

Mobile application is supposed to act as an interface for the end users to interact with the Parking Management Cloud. The application sends geo position, gP, of the vehicle along-with the radius $r = 0.5mi$ as parameters to the parking management cloud, $cMgtPark()$, function, as shown in (1):

$$lPrefP = cMgtPark(gP, r) \tag{1}$$

In (1), default value for r is set to 0.5mi, which means that list of preferred parkings, $lPrefP$, available at a radius of 0.5mi is fetched from the parking management cloud.

B. Parking Management (Cloud)

Parking Management (cloud), $cMgtPark()$, is the core module of the proposed smart parking system which finally rank the parkings. Working of the whole processing is presented in Algorithm 1.

Key processing of the proposed system is performed in the parking management cloud. Request for preferred parking with empty slots is forwarded to the parking management cloud, where multi-level filtering and ranking methods are used to return the preferred list of parking slots. Output of this process is the list of parking areas with empty slots at a distance of r from the current position of the vehicle.

To rank the list of parking areas and recommend drivers with the best option(s), the ranking module integrates multi-level filtering process, CO_2 prediction model (CO_2PM) and parking features & users sentiment data center (PFRD). This process can be completed by identifying a set of commonly used parking features and users sentiment and predicting the CO_2 level using CO_2PM.

The unique set of parking features researched [23] are shown in Table I which are stored in parking features and users reviews dataset (PFRD) and mathematically represented by (2):

$$PFRD = \{\text{Security}, \text{Sentiment}, \text{Organization}, \text{Cost}\} \quad (2)$$

TABLE I
PARKING FEATURES AND USERS' SENTIMENT

S.No	Features	Description
1	Security	Availability of watchman, surveillance system, road safety
2	Organization	Structure, spacing in slots, ease in entrance, parking and at exist
3	Sentiment	Cost @/hour
4	Cost	Positive/negative/neutral

CO_2 emission by a vehicle depends on a number of vehicle's features [24], [25]. To estimate the CO_2 emitted by a vehicle in focus, a CO_2PM is required. In this study, to create the required model, we have adopted the freely available "2020testcar-2020-03-03" dataset of vehicles, tested for fuel economy [26]. A sample dataset is shown in Table II.

TABLE II
"2020TESTCAR-2020-03-03" DATASET FOR CO_2PM CREATION

Model Year	Test Veh Make	Vehicle Type	H-power	# of Cylinders and Rotors	# of Gears	Test Fuel Type Desc	CO_2 (g/mi)
2020	Aston Martin	Car	600	12	8	Tier 2 Cert Gasoline	466.87
2020	BMX	Both	617	8	8	Tier 2 Cert Gasoline	617.33
.	.	.	.	.	.	.	.
2020	Mini	Car	134	3	7	Tier 2 Cert Gasoline	251.37

The prediction model is created by adopting EDA from machine learning field [27]. During search for preferred parking, the CO2PM is executed to predict the amount of CO_2 emission for the vehicle in focus. The estimated value is appended, as a new feature with $PFRD$, as shown in (3):

$$fSet = \{\text{CO2 emission}, PFRD\} \quad (3)$$

The generalized form of (3) is shown as:

$$fSet = \{f_1, f_2, \dots, f_n\} \quad (4)$$

These features are collectively used for ranking the parking areas. However, weights need to be computed for each of the features. To estimate realistic weights/importance score for these features, we have adopted Saaty's method [28]. The final weights, obtained, are presented in Table III.

The weights computed for each feature in the feature vector are pictorially represented in (5):

$$fWt = \{w_1, w_2, \dots, w_n\} \quad (5)$$

TABLE III
FEATURES' RELATIVE WEIGHTS

Feature	Weights
CO_2 emission	0.57269
Security	0.19348
Sentiment	0.13898
Organization	0.06873
Cost	0.02611

Once CO_2 is predicted and the features are identified and quantified, the outputs of CO2PM and PFRD are integrated. WSM [29] is used which is shown in (6):

$$WSM_i^{WSM_{score}} = \sum_j^n w_j * f_j^i \quad (6)$$

$where\ i = 1,2, \dots, m$ and *j = 1,2, …, n*

In the WSM, w_j , comes from (5) and f_{ij} from (4) where the literal "i" denotes the i[th] car park.

C. Continuous Updates on Smart Parking System Dataset (SPSD)

In this phase, physical hardware, such as ultrasonic sensor, raspberry pi, and camera are supposed to be used. These devices are used to properly park the vehicle at the available lot and consequently update the SPSD database. Along with these hardware resources, number plate recognition can also be used by using any of the available image recognition methods, such as [30] to automatically provide the SPSD with latest updates..

IV. EXPERIMENTAL RESULTS

To realize the proposed methodology, a scenario-based implementation is done.

Scenario: In the scenario, a city with 100 parking areas and 10 vehicles/cars is considered. The 10-sample cases, with vehicle characteristics, are shown in Table IV.

Datasets used: two datasets, "2020testcar-2020-03-03" [26] (see details Table II) and SPSD are used to realize the scenario. SPSD is a synthetically created dataset for 100 parking areas with parking features as shown in Table V.

TABLE IV
SAMPLE TEST CASES

V#	Test Veh Make	Vehicle Type	H-power	# of Cylinders	# of Gears	Test Fuel Type Desc
1	Aston Martin	Car	503	8	8	Tier 2 Cert Gasoline
2	BMW	Both	228	4	8	Tier 2 Cert Gasoline
.	.	.	.	.	.	.
10	Fiat	Both	160	4	6	Tier 2 Cert Gasoline

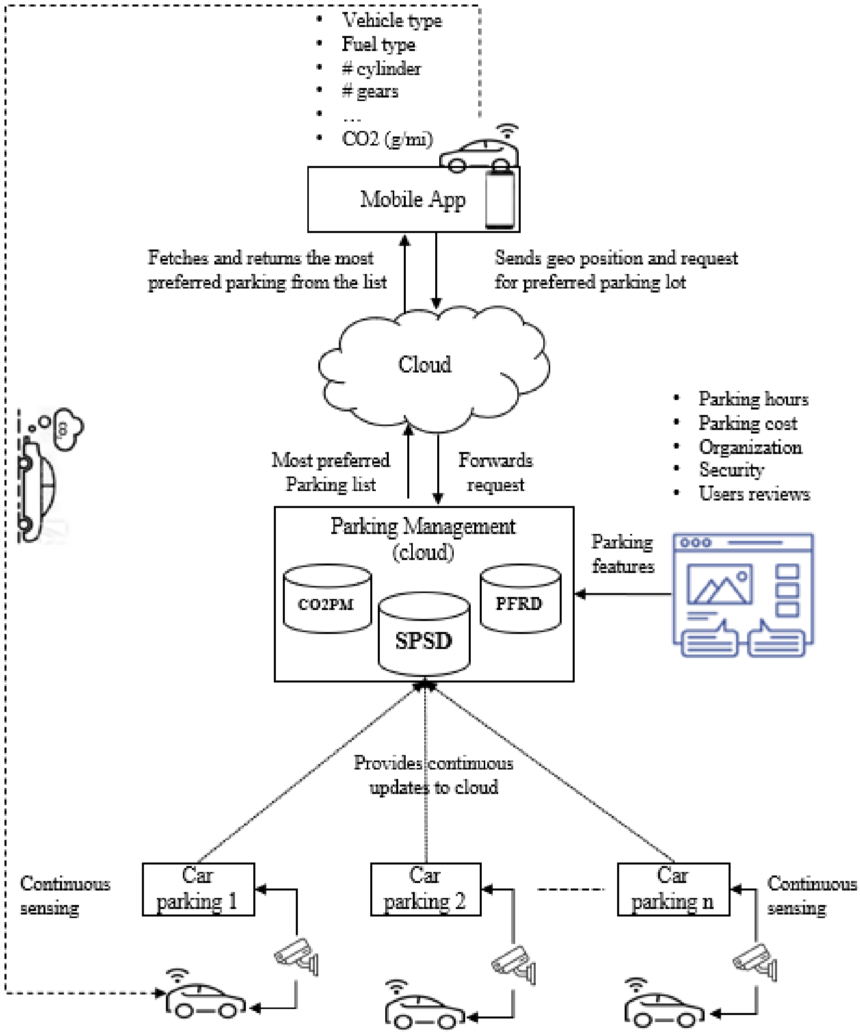

Fig. 1 Proposed framework for automatic smart parking system

Algorithm 1. Filtering & Ranking top-K parkings having empty parking slots
Begin

inputs:
$\boldsymbol{P} - \{p_1, p_2, \ldots, p_n\}$; *// the list of m parkings*
SPSD *- Smart parking system's cloud datacenter*
$\boldsymbol{fSet} = \{\boldsymbol{f_1}, \boldsymbol{f_2}, \ldots, \boldsymbol{f_n}\}$; // the list of n features as per ***eq.4.***
$\boldsymbol{fWt} = \{\boldsymbol{w_1}, \boldsymbol{w_2}, \ldots, \boldsymbol{w_n}\}$; // the list of weights for ***n*** features as per ***eq.5.***
output: $\boldsymbol{lPrefP}$; // the list of preferred, top *k*, parkings.

1. ***foreach*** *park* $\boldsymbol{p}$ *in* ***SPSD***
   topKempP < − the list of top *k* parkings at a distance *r* from geo position of the vehicle and having empty slots.
2. ***endfor***
3. ***foreach*** *park* $\boldsymbol{p} \in$ ***topKempP***
4. $WSM_i^{WSM_{score}} = \sum_j^n w_j * f_j^i$; *// where* w_j *is weight value in the weight vector* fWt, *assigned to feature* f_j, *in feature set* $fSet$ *for the* i^{th} *car park, where* $i = 1, 2, \ldots m$
5. ***endfor***
6. *sort* $\boldsymbol{WSM}$; *// in descending order*
7. *rank(*$\boldsymbol{WSM}$*); // rank the sorted WSM values to rank the parkings*
8. $\boldsymbol{lPrefP}$ *= pick the top-k ranked parking from the list*

End

TABLE V
SMART PARKING SYSTEM DATASET

P#	Parking hours	Empty slots	Security	Sentiment	Organization	Cost
1	open	y	0.7	0.2	0.3	0.2
2	open	n	0.3	0.7	0.5	0.1
	.	.	.	.	.	.
100	open	y	0.3	0.8	0.5	0.3

Experiments and results: the following experiments are performed.

Experiment1: In the first experiment, multi-level filtering procedure is executed. Each vehicle, in the scenario, sends its current GPS location with parameter *r = 0.5mi* to the smart parking cloud., which exploits SPSD to retrieve the list of all available car parks at a distance 0.5 mi, currently opened, having empty slots. A sample of the results is shown in Table VI.

TABLE VI
RESULTS OF THE MULTI-LEVEL FILTERING APPROACH

P#	Distance in mi (r)	Parking hours	Empty slots	Security	Sentiment	Organization	Cost
5	0.35	open	Y	0.1	0.9	0.1	0.2
8	0.20	open	Y	0.2	1.0	0.4	0.8
.	.	.	.	.	.	.	.
90	0.4	open	Y	0.8	0.6	0.7	0.4

Experiments2: In this experiment, CO2PM predicts CO_2 and a few results obtained are shown in Table VII.

TABLE VII
RESULTS OF CO_2PM CREATION

V#	CO_2 (g/mi)
1	259.04
2	296.47
.	.
10	258.69

Experiments3: Before executing the ranking methodology, outputs of CO2PM and multi-level filtering procedure are integrated. In our scenario case, a list of 20 parking areas is considered for ranking using weighted sum model. For example, for vehicle #1's predicted CO_2 (*259.04* g/mi), the list of few alternative parking areas is shown in Table VIII.

TABLE VIII
THE LIST OF CANDIDATES PARKINGS WITH THEIR FEATURES

P#	Distance in mi (r)	CO_2 (Est) Emission	Security	Sentiment	Organization	Cost
5	0.3501	90.70	0.11	0.91	0.11	0.22
8	0.2018	52.28	0.23	1.00	0.42	0.83
.	.	.	.	.	.	.
90	0.3504	90.77	0.82	0.60	0.70	0.38

For applying algorithm 1, the values of Table VIII are normalized and WSM scores are computed for them. The WSM scores are used for ranking as shown in Table IX. In this table, ranking of a few parking areas out of the total 20 areas, in the range of r = 0.5 mi, for the scenario's ten vehicles. The last column 'Ranking of V#10-V#1' shows rankings for the parking areas, at column 1st (i.e., 'Parking #'). The mobile app recommends top-k (k = 3) parks to the drivers.

TABLE IX
RANKING RESULTS OF WEIGHTED SUM MODEL

Parking #	Ranking of V#10-V#1
29	20
.	.
66	3
50	2
27	1

V. VALIDATION AND EVALUATION

To validate whether the parks recommended by the proposed methodology are the preferred ones and will really lead to minimum level of CO_2 emission, conventional evaluation method is used. In this method, as no baseline system is available in the literature to compare with the proposed methodology, therefore we considered a scenario in which the parking areas are randomly selected by drivers of the ten vehicles. A random query is executed 10-times for the 10-vehicles over the 20 available parking areas to determine the level of CO2 emission. Results are compared with results of the proposed smart parking system, shown in Fig. 2.

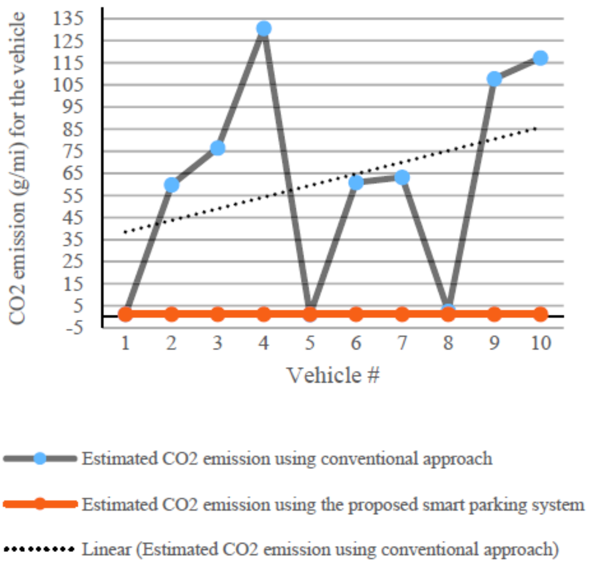

Fig. 2 Comparison of the proposed smart parking system with the conventional approach

Comparison results show that in conventional approach, 3/10 vehicles could manage to find the preferred parking slots as compared to the proposed smart parking system approach where 10/10 vehicles succeeded in finding the preferred parking slots. Overall, the ratio of CO_2 emission using conventional and the proposed methods is 620.9(g): 12.5(g) for the 10-vehicles over the 20 available parkings.

VI. CONCLUSION

In this paper, a smart parking system is proposed which uses EDA, multi-level filtering and weighted sum models for exploiting parking and vehicles features to rank the available parking areas. The proposed methodology ranks all the available parking areas using multiple criteria and gives option(s) of the preferable parking areas. The features are weighted and highest weight is assigned to CO_2 emission rate of the vehicle, therefore the methodology ensures the selection of a parking area that leads to minimum level of CO_2 emission. The comparison results show that the proposed methodology helps in reducing the CO_2 emission.

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