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A Hybrid AI–ML Approach for Smart Traffic Regulation and Automated Parking Detection

Suchetha N V[1], Pranathi R Jain[2], Preethu J Naik[3], Sanath[4] and Shanavi B A[5]

[1]Associate Professor, Department of Computer Science & Engineering, Sri Dharmasthala Manjunatheshwara Institute of Technology Ujire Karnataka, India
[2,3,4,5] BE Scholar, Department of Computer Science & Engineering, Sri Dharmasthala Manjunatheshwara Institute of Technology, Ujire, Karnataka, India

Correspondence should be addressed to Suchetha N V; itsmesuchethanv@gmail.com

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ABSTRACT- Congestion, poor parking, and excessive use of fuel have become serious issues that have emerged due to the high pace of urban traffic buildup. Traffic Spacing and Management System Parking Space Detection is another solution to these problems, and it will be developed based on smart sensing and communication technology. This system checks on the motion of vehicles, controls the movement of traffic and identifies parking spaces available in real time. The system gathers data on the traffic using a network of sensors and microcontrollers and sends it to a central controller that controls the timing of the signals and maintains traffic flow. Moreover, the parking sensors are installed to detect empty spots and notify the drivers via a mobile app or a display board, which saves on time wastage in finding a parking space. The suggested system enhances the safety of the road, decreases the congestion, and uses the urban parking spaces better. This project is an effective and sustainable solution to the transportation management of cities today as it combines the IoT technology, wireless communication, and intelligent traffic control.

KEYWORDS- Traffic Management, Parking Space Detection, IoT, Wireless Sensor Network, Smart City, Embedded System, Real-Time Monitoring, Traffic Control, Automation, Vehicle Detection

I. INTRODUCTION

It is becoming a headache to a city as more cities are growing and the vehicles are increasing. Commuters are subjected to traffic jam, traffic jams, and parking space that is hard to locate. These problems lead to frustration, augment the travel time, contribute to pollution and raise safety issues. Due to this, there is a high demand of smarter solutions that will enhance traffic flow and simplify the parking process.

The proposed project presents a Traffic Spacing and Management System and Parking Space Detection that will enhance the efficiency, safety and convenience of urban living.

The primary goal is to facilitate a better passage of traffic and minimize congestions through appropriate the spacing of vehicles with the aid of sophisticated sensors and real-time information analysis.

This system is based on intelligent sensors, persistent data monitoring, and smart algorithms to monitor traffic conditions on the real-time basis. It tries to reduce traffic jam, reduce risk of accidents as well as enhancing the overall performance of the road by controlling the distance between vehicles and controlling traffic.

Besides controlling traffic, the project has a parking space detection option. Cameras, ground sensors, and data analytics will allow the system to monitor the parking availability and immediately inform the drivers about the availability of open spaces. This will save time in search of parking space and diminish the unnecessary movement of the vehicle and will assist in reducing congestion and emissions.

In sum, this hybrid system will be better to the driving experience in the city as it will efficiently manage traffic, make the roads safer, and help maintain environmental balance. The system promotes traffic spacing management and parking detection, which will therefore promote a smoother traffic flow, easier parking and livable urban environments.

II. RELATED WORK

A survey of the urban traffic management systems with the application of Wireless Sensor Networks (WSNs) has been introduced by Kapileswar Nellore and Gerhard P. Hancke[1]. Some of the traffic management schemes that are reviewed in the study include congestion avoidance, emergency vehicle priority, and minimization of the Average Waiting Time (AWT) at the intersection. It is also addressing the architecture of systems based on WSN, and how sensor nodes play an important part in monitoring vehicle flow, density, and speed.

A detailed literature review of the urban parking systems by J. Param, P. Das et al. [2] has brought out the role of rapid economic growth, ineffective policies and subsidies that have led to the rise of individual car usage and thus, parking has become one of the most significant problems of traffic management. Their analysis focuses on the problem of poor coordination between the policies of parking and traffic operations that creates a block to the free movement of traffic and the needless utilization of resources. The authors also address the issues of parking, the major parking

features, the demand modelling strategies, and the impact of the elements, including access, walk time, parking charges, guidance systems, management. Their review can turn out to be useful knowledge to planners and policymakers in order to enhance the development of better planning, design, and evaluation of parking systems.

An A. M. Al-Sarawi et al[3] have introduced a Traffic Management Systems: A Classification, Review, Challenges and Future Perspectives. The paper breaks down systems into reactive, proactive and predictive in terms of their modes of operation and discusses sensor, communication network and data processing algorithms usage. It is also a combination of IoT, cloud computing and artificial intelligence to increase the adaptability and performance of the system.

The extensive survey on the management and control systems of the urban traffic has been suggested by M. S. S. Khan and M. A. Khan [4]. The system offers traffic control plans like fixed-time, actuated and adaptive control plans and the portion of Intelligent Transportation Systems (ITS) and IoT in the real-time monitoring. It also utilizes Golomorphic Information Systems (GIS) in decision-making and spatial analysis.

M. S. S. Khan and M. A. Khan [5] have developed a detailed work on the safety aspect of traffic control systems. One of the key elements in urban traffic control described in the paper is the safety-focused design, and the technologies addressed include collision avoidance, pedestrian identification, and emergency vehicles prioritization. The system employs the high-tech sensors, comms and driver conduct examination to bolster the road security

Rout et al. [6] have introduced a detailed review of the Intelligent Traffic Management Systems (ITMS), its components, features, and difficulties. The paper focuses on artificial intelligence, machine learning, and big data that can be used to optimize traffic and anticipate congestion. Its further deals with such challenges as high implementation cost and data privacy, proposing modular architecture and collaboration between the public and the private to improve the efficiency of urban traffic management [6].

The application of the Internet of Things (IoT) to the creation of intelligent traffic management systems was discussed by S. S. Patil and A. R. Alagundagi[7]. In their work, they talk about IoT-based schemes that imply sensors, communication schemes, and data processing to monitor and control real-time traffic. They emphasize the importance of cloud computing and mobile applications in sharing information about traffic and solve such a problem as the security of data and interoperability of the systems. The authors propose standardized protocols and edge computing to enhance the performance, which is important information to the IoT and its potential to transform the traffic management.

M. S. S. Khan and M. A. Khan [8] discussed different approaches to solving the problem of urban traffic congestion and improvement of mobility. They have divided the techniques of traffic management into the conventional methods, which include widening of the road, use of fixed-time signals and the contemporary intelligent systems which dynamically respond to the road conditions. Other sustainable practices such as encouraging people to use public transport, cycling, and congestion pricing were also highlighted by the authors. They made a conclusion that efficient and responsive urban traffic systems can be developed with the help of combining conventional methods with intelligent technologies and sustainable practices.

Biyik, Zaheer Allam et al. [9] provided a review on smart parking systems, which covered sensor-based, camera-based, and hybrid architectures. The research paper illustrates the advantages and weaknesses of both systems with concerns such as reliability of communication, privacy of data, and scalability being made. The authors suggest the creation of unified systems, the incorporation of the latest data analytics, and the implementation of sustainable business models to improve the future smart parking systems.

Maddu et al. [10] proposed FiskeMultiNet which is a real-time multi- task deep learning model in automated parking systems. The network uses the input of four fiske cameras to detect objects, semantically segment, and detect soiling at the same time. it is maximally efficient in shared features through the process of multi-task learning; it can run at 15 FPS on low-power embedded platforms. The authors also published a set of 5,000 annotated images to conduct more studies in intelligent transportation systems.

A one-stage convolutional neural network (CNN) was suggested by J. K Suhr et al. [11] to detect parking slots in the images of an around-view monitor (AVM). Their model incorporates the global and local information to precisely locate the parking slots without the region proposal phase. The end-to-end trainable system improves the real-time performance and attains 100 percent type classification and 99.31 percent occupancy accuracy with a 60 FPS, which is ideal in intelligent parking applications.

Zhao et al. [12] proposed PSDet, which is a two-stage deep learning model that recognizes parking spaces in real time with the use of circular descriptor and coarse-to-fine approach. They have big benchmark data, which enhances generalization and test results indicate good accuracy with real-time performance.

Li et al.[13] created a model with HPS-Net which is a one step model that directly predicts the four corners of a parking slot by employing a polygon-based method. The VPSD and PS2.0 data tests produced high F1-scores of 0.92 and 0.99 making it accurate and efficient.

Zhang et al. [14] suggested a roadside parking detection scheme that uses the magnetic sensors with RSSI data. It is a hybrid method that can enhance the accuracy of vehicle detection, increases the lifetime of detector batteries, and is a cost-effective solution to smart parking.

The article by Chen Min et al. [15] described the attentional graph neural network-based parking slot detection approach, where the marking points become the graph nodes. It is a good way to capture spatial relations and gives good and reliable real-time detection with no complex post processing required.

Sharma et al.[16] conducted the review of smart parking technologies, which included sensors, communication systems, and software designs. They state the necessity of dependable and low-power sensors and comment on the tendencies, such as predictive analytics and booking services, and interoperability, privacy, and environmental impact issues.

The article by Al Mamun et al.[17] is about an IoT-based smart parking system designed by the author along with sensors and a mobile application to offer information on the availability of spaces in real-time. It has an OLED display and a scalable and user-friendly solution to smart cities in

the system.
Bui and Suhr [18]suggested two-stage CNN, first to locate slot entrances, and secondly to locate them in detail with multi-scale features. This will enhance precision in classifying and orienting, and it will facilitate autonomous parking.
Al-Otaibi et al.[19] developed an IoT parking system that monitored real-time parking spaces on a cloud platform, which was based on sensors, microcontrollers, wireless networks, and a mobile application. It facilitates bookings, navigation and effective space control.
Ke et al. [20] designed a smart parking surveillance system with the help of edge AI and an improved SSD model to detect vehicles in real-time. It has more than 95 percent accuracy, less dependence on clouds, and enhanced privacy, scalability and flexibility.

III. PROBLEM STATEMENT

In the present days, as cities are constantly expanding, the problem of traffic control has become significant. The streets are getting congested, and the drivers usually have a hard time with the slow-paced traffic, unreasonable distances between the cars, and the constant inconvenience of trying to find an empty parking place. These not only waste time, but also fuel consumption, frustrate, contribute to the increase in pollution, and also led to an increased risk of accidents. The current traffic management systems are generally outdated and cannot offer real time information and smart control and thus cannot effectively manage the current complex traffic ways in an urban environment.
At the same time, the absence of a system capable of controlling the movement of vehicles on the road and assisting drivers in finding parking fast is one of the largest issues. Lack of real- time monitoring and intelligent decision-making will make the traffic movement inefficient, and the search of the parking will be a burden on the already overcrowded streets.
In response to this, a smart, integrated solution that would ensure tracking of spacing between traffic and identification of parking availability in real-time will be required. Traffic Spacing and management system and parking space detection can be used to ensure safe distance between vehicles and reduce congestion as well as directing drivers to vacant parking spaces. With such a system, safety can be enhanced, delays can be minimized, and aids can be provided greener and efficient city transportation system.
The Proposed System Objectives.
The Objectives of the proposed project are the following, and each of them will be devoted to the removal of the existing challenges and the gaps of the current digital payment system by means of the blockchain integration:

- Keep a Fitting Distance Between Vehicles: Keep vehicles apart using live speed up information in order to minimise sudden braking, collisions and traffic flowing in an orderly manner.
- Constant Tracking of Traffic State: Can be used as smart sensors that keep a constant check of road traffic, and be able to make a quick modification that enhances traffic and minimize.
- Detect Available Parking Space in Real Time: Sensors and cameras can detect an open parking spot in real time, providing the driver with accurate information without having to guess whether a parking space is available or not.
- Guide Drivers to Empty Parking Effectively: Guide drivers to free parking spots in real time, save time on searching and decrease stress levels in car drivers.
- Less polluting and wasting fuel: Drive less, less idling, and avoid the intermittent searching of parking areas, and contribute to the reduction of emissions and fuel usage.
- Make Driving More Convenient: Traffic spacing and parking detection in a single system will reduce the burden of city driving, making it more comfortable, safe and predictable.

Improve Road Safety: All Users: Spacing of vehicles and flow should be improved to minimize the chances of rear-end collisions and unexpected traffic stops.
At the national level, the country must encourage sustainable urban mobility: Organized traffic movement and more efficient parking, all leading to cleaner cities that are much livable.

IV. METHODOLOGY

The design of the Traffic Spacing and Management System in which Parking Space Detection is designed is a definite practical process that is directed towards enhancing the movement of vehicles in the city as well as the way people locate parking spaces. The key steps followed to construct the system are listed below:
Requirements Analysis and Technology Selection: First, the objectives of the system are well-known, and this results in less congestion, better vehicle spacing, and assisting the drivers to find the parking position simply. According to these requirements, appropriate technologies such as IoT sensors, microcontrollers, communication modules, and cloud platform are selected.

- System Architecture Design: A full design of the system will be prepared so that how all the parts will interact with each other is displayed. This will involve placement of sensors, flow of data in the system and provision of real time information to the users about traffic and parking
- Sensor Deployment and Data Collection Traffic sensors and parking sensors are deployed in strategic areas. These devices gather real-time data of vehicle movement, congestions and parking places. To achieve precise data, they are tested and calibrated.
- Data Processing and Analysis: Sensor raw data is decontaminated and processed with inbuilt algorithms. Traffic routes are monitored to identify congestion whereas parking information is examined to locate vacant spots. Immediate updates make sure of quick content communications.
- There is Route Optimization and Parking Guidance Smart algorithms are created to propose optimal paths and closest available parking lots. They take into account live traffic information, distance and comfort of the user in order to drive along the road easily and save time and unnecessary waste.
- User Interface and Navigation Support: An easy-to-use interface is created to facilitate drivers. It displays the state of traffic, free parking places, and recommended routes. This will be aimed at making the experience understandable and user friendly.

- System Integration and Communication: Every component of the system sensors, servers, algorithms, and the user interface are all linked together in a secure way. This makes sure that the data runs properly and all the components operate without delays.
- Testing, Validation and Performance Checks: The system is checked with the various types of traffic to realize the accuracy, response time and stability. Parking detection and congestion prediction are verified so that they can be used in real-life performance.
- Deployment, Monitoring and Maintenance: When the system is deployed, it is monitored continuously in order to identify any problem in good time. Maintenance, updates and improvement done on a regular basis almost guarantee smooth running of everything in the long run.
- User Awareness and Training: The guide and instructions are simple to ensure that the users know how to use the system. This makes them have confidence and enjoy the traffic and parking amenities to the maximum.

V. SYSTEM DESIGN

The proposed b Traffic Spacing and Management System with Parking has a system architecture, as shown in Figure 1.

- Space Detection- It is made up of major elements, such as user interface(UI), Sensor and data infrastructure,Traffic flow, least congested route, parking space detection, detect free spaces, system integration, store data.

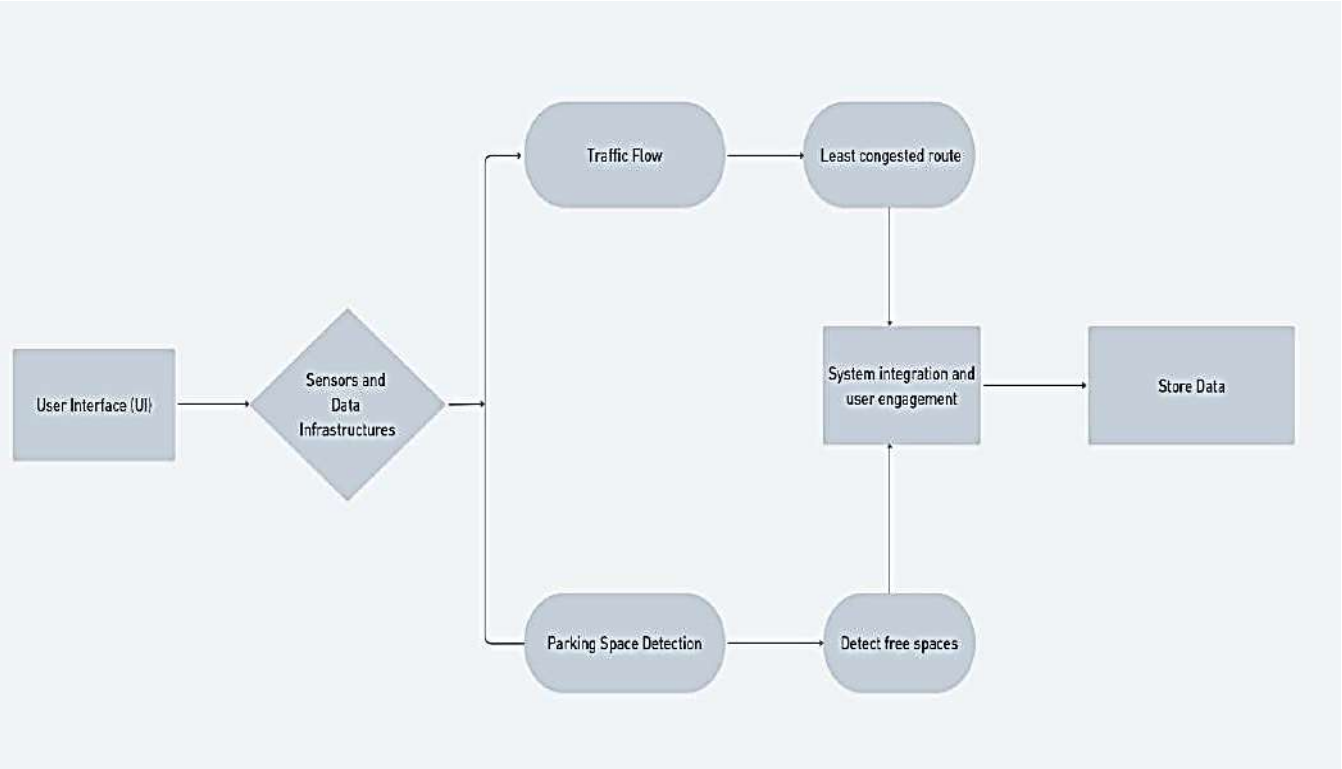

Figure 1: System Architecture of a Hybrid AI–ML Approach for Smart Traffic Regulation and Automated Parking Detection

- User Interface (UI): The User Interface is a source of interface between the system and the user. It shows real time traffic and parking space. It is meant to make it easier to interact with and provide easy navigation facilitation.
- Sensors and Data Infrastructures: Sensors on-going: Get live data like the traffic congestion, movement of vehicles and availability of parking spots. This information is sent to the infrastructure in the system to be processed. The sensors guarantee precise and real-time information that can guide the system to be effective, as well as make decisions that are smarter.
- Traffic Flow: Traffic flow data is a market indicator that shows the flow of vehicles in various roads. The system examines the extent of congestion, change of speed and the loads on the route. Through processing such patterns, we are able to get an insight into the present road conditions and direct the users to the quicker and smoother routes to get to their destinations.
- Least Congested Route: This is a data-based on the traffic flow that the system recognizes routes with the least traffic congestion. It is used to compare the various segments of roads and the most efficient is chosen. This feature will assist the users to save time and a lot of frustration as they will not need to spend a lot of time in traffic jams anymore.
- Parking Space Detection: The parking sensors identify whether individual parking spaces are open or not. The information is updated and processed in real time. The system will utilize this information to direct users to vacant parking slots and will save them on wasting time going in circles and enhance efficiency in parking.
- Detect Free Space: The system filters the information of the parking sensor to only show the free space. These

open spaces are shown to customers accompanied by location information. This saves time and fuel as they do not have to go around the parking area searching for the right parking space.

- System Integration and User Interaction: All the information about traffic and parking sensors is systematically combined. This cohesive platform interprets information and puts it across to the users in a comprehensible manner. The system will enhance the level of user interaction by ensuring correct guidance, timely guidance, and trustworthy interactions.
- Store Data: This is where all data concerning the collected traffic and parking data is stored so that it can be analyzed in the future. Such stored data can be utilized to define long-term trends, enhance system performance, refine routing algorithms and help at a later stage to plan the urban traffic more appropriately.

A. Algorithms Used

Adaptive Signal Algorithm The adaptive signal algorithms are applied to control the traffic lights dependent on the real movement and volume of vehicles at an intersection. The system is not limited to a set cycle, but it constantly monitors the number of vehicles, the length of the queue, and the occupancy of the lanes and changes the duration of the green-light accordingly. Through these patterns that are available in real time, the algorithm spends more time on busy lanes and less time on waiting times that have lesser traffic. This is useful in the process of ensuring the smooth flow and avoids unnecessary idling as well as sudden congestion at signal points. In general, the adaptive control would help in safer inter-vehicle spacing, reduce fuel wastage, and enhance the effectiveness of the road in general.

- Optical Flow Algorithm: The optical flow algorithm is applied in determining the movement of the vehicles on the highway by examining the variation between the successive video frames. They follow motion direction and velocity of movement depending on pixel changes which create motion vectors per pixel of the frame. When used on roads, thematic maps display the general direction of traffic, which can be used to find out where the traffic slows or stalls, or where the traffic flows smoothly. This information is used to assess the real time traffic behaviour and modify the management strategies.

Optical flow is particularly handy when it comes to identifying sudden velocity shifts and maintaining continuous monitoring of more than one lane. [19].

- OpenCV Traditional Algorithm: OpenCV -based methods are applied in parking systems to determine whether a parking slot is free or occupied by observing the features of the images without complicated learning models. All the difficulties tend to require turning the camera feed into grayscale, doing thresholding or edge detection, and isolating each parking slot area. Depending on comparing the current frame with predefined templates of empty slots, or disagreeing intensity changes, the system can detect the presence of a vehicle or not. These methods are lightweight, fast and can be used to monitor in real-time provided the conditions are under stable lighting. They assist in the swift refresh of parking availability and provide a viable answer in cases where the computational resources are scarce. [18].

VI. SYSTEM IMPLEMENTATION SNAPSHOTS

Below the Figure 2 to Figure 6 are snapshots of the built blockchain-based BlockPay system prototype that shows the functional modules that are critical such as transaction validation, RESTful API- based interaction, and progressive creation of blockchain data blocks.

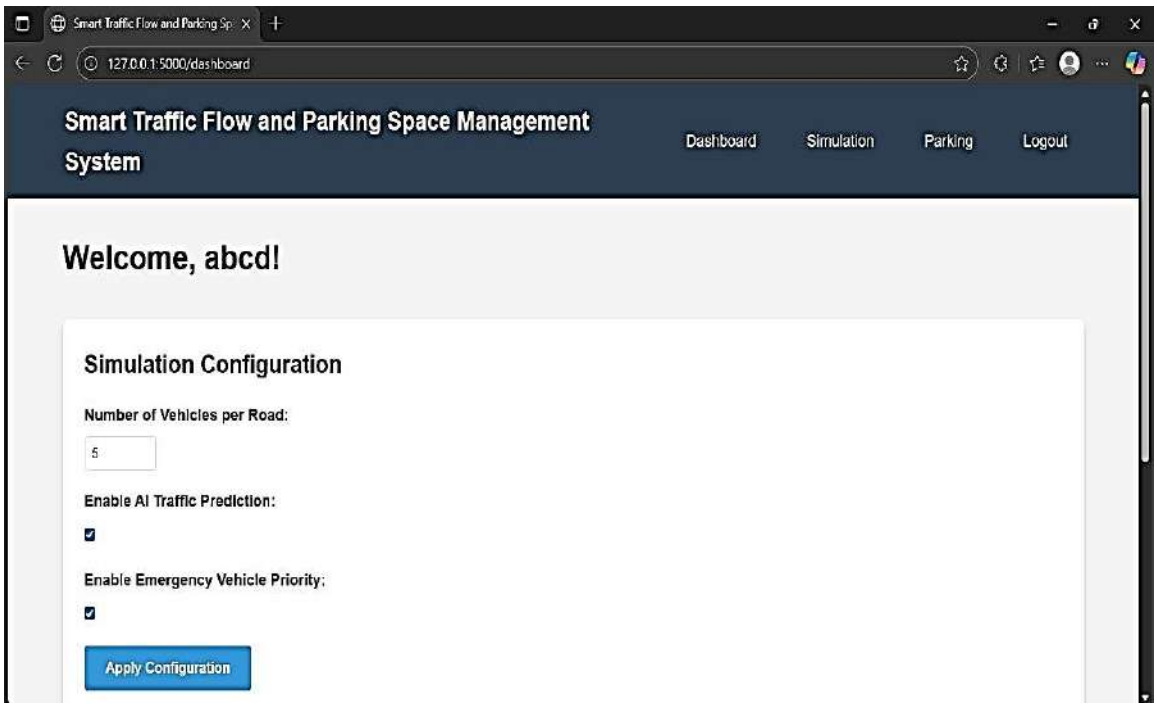

Figure 2: Front Page

In particular, Figure 2 represents the interface of transaction validation, which includes dynamic calculation of the balance and the metadata of the transaction.

Figure 3: Simulation Page

Figure 3 shows the account balance which is dynamic in USD and gives specific user wallet status.

The identity configuration mechanism is shown in Figure 4 through a username set-up prompt.

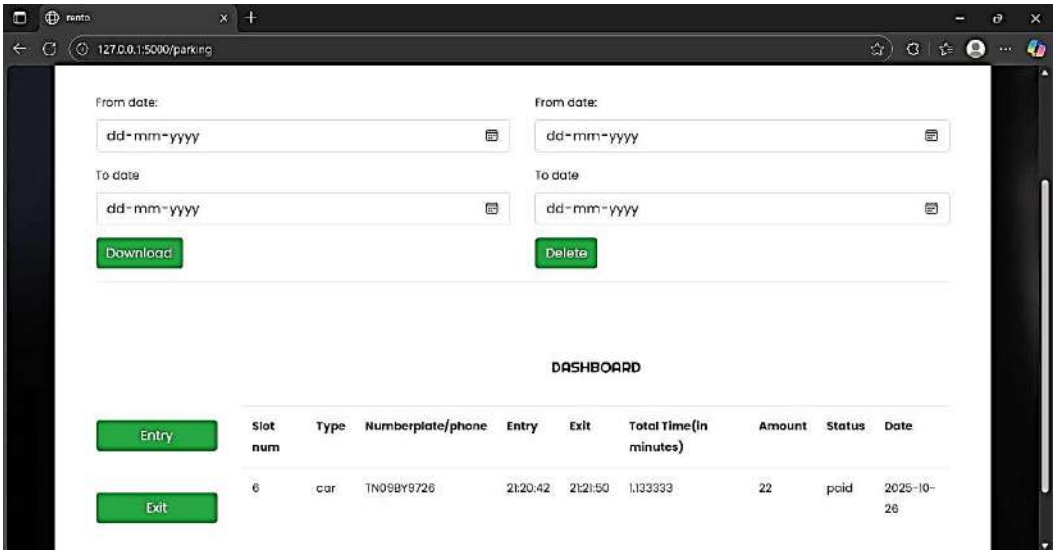

Figure 4: Parking Space Page

The initiation and confirmation of transactions are illustrated in Figure 5 where the users enter payment information including the amount of crypto-currency to be used, the source address, and additional message with confirmation dialogs. Put together, these interfaces certify the feasibility of operation, usability of the system, and the realisation of the proposed architectural model.

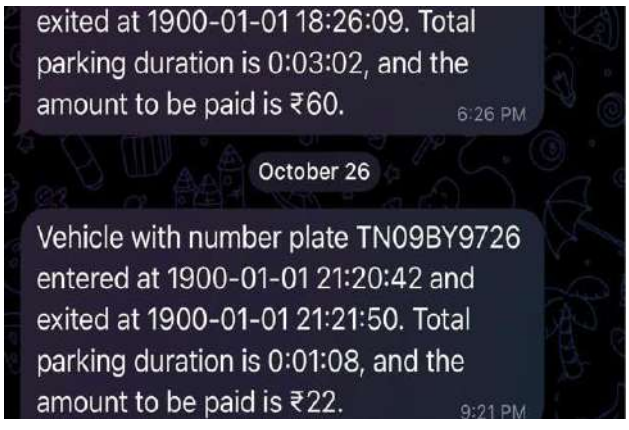

Figure 5: ChatBot

VII. CONCLUSIONS

Traffic Spacing and Management System with Parking Space Detection is developed in order to make the daily travel easier, safer, and much less stressful. The system assists in controlling the traffic flow of vehicles on the road through smart sensors and real-time monitoring, eliminates unnecessary traffic congestion, and makes the traffic flows more natural. This implies reduced road congestion, improved road safety, and enhanced traveling experience to all people. The parking space detection feature of the system is one of the most useful features of the system. The system displays available spaces immediately as opposed to the drivers taking time to manoeuvre around in search of a free parking space. This not only saves time, reduces fuel use but even it reduces the pollution caused by idling vehicles. In general, this system brings to emphasis the role of technology in making life in cities indeed better.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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ABOUT THE AUTHORS

Dr. Suchetha N V has completed her B.E in the year 2011, MTech in the year 2015 from VTU Belagavi, and Ph.D. in the year 2024 from VTU Belagavi. Her areas of interest are Image Processing and Deep Learning. She has published 13 international research papers. She is the life member of Kannada Sahitya Parishad.

Pranathi R Jain received her B.E. degree in Computer Science and Engineering from Visvesvaraya Technological University (VTU), Belagavi. Her areas of interest include Deep Learning, the Internet of Things (IoT), and Artificial Intelligence (AI). She was a student in the Department of Computer Science and Engineering at SDM Institute of Technology, Ujire.

Preethu J Naik received her B.E. degree in Computer Science and Engineering from Visvesvaraya Technological University (VTU), Belagavi. Her areas of interest include Deep Learning, the Internet of Things (IoT), and Artificial Intelligence (AI). She was a student in the Department of Computer Science and Engineering at SDM Institute of Technology, Ujire.

Sanath received his B.E. degree in Computer Science and Engineering from Visvesvaraya Technological University (VTU), Belagavi. His areas of interest include Deep Learning, the Internet of Things (IoT), and Artificial Intelligence (AI). He was a student in the Department of Computer Science and Engineering at SDM Institute of Technology, Ujire.

Shanavi B A received her B.E. degree in Computer Science and Engineering from Visvesvaraya Technological University (VTU), Belagavi. Her areas of interest include Deep Learning, the Internet of Things (IoT), and Artificial Intelligence (AI). He was a student in the Department of Computer Science and Engineering at SDM Institute of Technology, Ujire.