

Smart Parking Management System “MOTAH”

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How to cite this paper: Alansari, I., Alnamlah, G., Abdulllah, R., Alluqmani, J. and Alzahrani, A. (2024) Smart Parking Management System “MOTAH”. *Journal of Software Engineering and Applications*, 17, 541-552.

<https://doi.org/10.4236/jsea.2024.176031>

Received: May 5, 2024

Accepted: June 24, 2024

Published: June 27, 2024

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Abstract

With a surge in the university’s student and staff population, parking problems and congestion have rapidly intensified. The recent inclusion of women drivers, particularly during official working hours, has exacerbated these challenges. This pressing issue underscores the critical necessity for a structured approach to managing university entries and overseeing parking at the gates. The proposed smart parking management system aims to address these concerns by introducing a design concept that restricts unauthorized access and provides exclusive parking privileges to authorized users. Through image processing, the system identifies available parking spaces, relaying real-time information to users via a mobile application. This comprehensive solution also generates detailed reports (daily, weekly, and monthly), aiding university safety authorities in future gate management decisions.

Keywords

Car Parking, Traffic Density Estimation, Intelligent Transportation, Congestion, Control, Parking Arrangement, Parking Behavior

1. Introduction

The urban population is on a rapid rise, with projections indicating an additional 2.5 billion people in major areas by 2050 [1]. In response, city planners seek automated technology solutions to ensure the comfort, safety, and balance of urban dwellers. Collaborating with solution providers and IoT software manufacturers aim to develop smart parking and traffic management systems aimed at alleviating congestion in congested areas. Expanding parking spaces won’t singularly resolve traffic congestion in densely populated cities. Instead, the focus shifts to optimizing existing spaces through smart parking technology. By implementing algorithms, we aim to tackle parking challenges effectively, offering real-time guidance to drivers regarding crowd density, arrival times, and available parking spots within a smart parking framework [1].

2. Background

Artificial Intelligence (AI) is a wide-ranging branch of computer science focused on creating intelligent machines that respond and perform tasks like human intelligence. AI has several uses, including speech recognition, computer vision, robotics, machine learning, and expert systems, and natural language processing. Computer vision is a disciplinary scientific field that deals with how computers can gain a high-level understanding of digital images or videos. It is a very vast field in computer science. Various projects around the globe being developed are purely in computer vision such as parking systems, auto-driving vehicles, self-driving drones, etc. [2]. On the other hand, Machine learning is about teaching programs to learn and adapt by analyzing data. It creates models to understand hidden patterns in data, which are then used to make predictions or suggestions when given new data. Evaluation metrics are used to measure the performance of these models. There are two main types of machine learning: supervised and unsupervised. Supervised learning uses pre-labeled data to train models for tasks like classification and regression, while unsupervised learning doesn't require labeled data and is often used for tasks like clustering. Another type, semi-supervised learning, uses both labeled and unlabeled data for training, with a small amount of labeled data alongside a larger amount of unlabeled data. Additionally, there are various other types of learning tasks, such as transfer learning, sparse learning, reinforcement learning, and ensemble learning [3].

Deep learning is a subfield of machine learning technique that teaches computers to learn as learning by example. Deep learning is a key technology behind many technologies like driverless cars and speech recognition. It is getting lots of attention lately as it is achieving results that were not possible before. In deep learning, a computer model learns to perform classification tasks directly from images, text, or sound. Deep learning models can achieve state-of-the-art accuracy that sometimes exceeds human-level performance. Models are trained by using a large set of labeled data and neural network architectures that contain many layers. There are several popular deep learning models briefly, which include deep recurrent neural network (RNN), and deep convolutional neural network (CNN) [4]. RNN is an unsupervised learning algorithm that uses sequential or time series data. It remembers previous inputs to influence the current ones, making it effective for tasks like time series prediction. Its ability to retain information over time, especially with Long Short-Term Memory, is a key advantage. RNNs can also be combined with convolutional layers to broaden their applicability [4]. CNNs are neural networks designed for data classification by learning distinct features. They automatically learn characteristics, like differentiating cats from dogs, by analyzing training data. While recurrent nets excel with sequential data, CNNs have significantly advanced image, video, speech, and audio processing [4].

The computer vision system Roboflow is a branch of the machine learning community that allows more efficient methods for data collection, preprocess-

ing, and model training, and enhances performance by its efficient parameters readily available to use. For use cases including gas leak detection, plant vs. weed detection, airplane maintenance, roof damage estimator, satellite imagery, self-driving vehicles, traffic counter, garbage cleaning, and many more, Roboflow is used in a variety of computer vision sectors [5].

Google Maps, a groundbreaking innovation by Google Inc., revolutionized navigation for nearly 64 million users. With features like street view and locating essential facilities, it relies on advanced algorithms and vast datasets, ensuring accuracy and real-time information. Predictive features based on traffic patterns enhance user experience, although unforeseen events may occur. Continual updates and new features ensure Google Maps remains a reliable and indispensable application [6].

3. Related Work

Rising population and daily traffic congestions have intensified vehicle parking and transportation issues. Rather than continually expanding parking spaces, an efficient technological approach is crucial to optimize existing space utilization. Smart parking solutions, employing sensors and software, provide real-time maps of available spaces for drivers and operators. This research highlighted several key data points such as statistics showcasing the growth trend of parking and the increase in the number of vehicles on campus. Additionally, it referenced studies on traffic congestion within the university premises, citing instances of peak hours where parking availability becomes severely limited. These data points serve to underscore the pressing nature of the parking issues faced by our university community and provide a solid foundation for the need for an intelligent parking management system.

Several innovative solutions have been proposed. Kaarthik, K., Sridevi, A., Vivek, C. (2017) propose an intelligent parking system utilizing image processing [7]. Rachid SOUSSI *et al.* (2011) developed a Wireless Sensor Network-based system allowing real-time parking monitoring and reservation [8]. Prof. D. J. Bonde *et al.* (2014) designed an Android-controlled automated car parking system, while Zahid Mahmood *et al.* (2018) proposed an advanced system integrating object detection and real-time face recognition for enhanced security and management [9] [10].

Moreover, the subsequent applications have been developed:

- Thaki: Launched in 2021, Thaki is a smartphone app for booking and paying for public road parking. It offers services such as parking reservations, payment of irregularities, subscriptions, and parking fees. Advantages include language support, clear meters, GPS guidance, and safety due to official affiliation. Disadvantages are that it's not free, has customer complaints about ticket fees, lacks single payment options (forcing a 60 SR package purchase), and can be slow [11].
- Mawgifi: Launched in 2018 and updated in 2021, Mawgifi locates and pays for parking at on and off-street locations. Features include parking management,

e-wallet account management, vehicle status tracking, and notifications. It supports Arabic and English. However, it is not free and manual entry for invoice scanning is cumbersome as it doesn't allow pasting copied numbers [12].

- **Traffic Cam:** Launched in 2017, Traffic Cam allows users to check road traffic and weather conditions with access to 32,000 cameras globally. Features include dynamic camera display, easy browsing, swipe navigation, zooming, live view refresh, portrait and landscape modes, snapshot saving, and sharing via social media. Cameras are regularly updated. Disadvantages include lack of Android support and that it is not free [13].

- **OParking:** OParking is an affordable and user-friendly app for fast parking payments with a simple interface, requiring only a phone number for registration. There are no SMS charges or prepayment required. Disadvantages include the app not functioning properly and that it is not free [14].

4. System Analysis

This section comprehensively addresses key aspects of the development process for a parking application, encapsulating system analysis, requirements elicitation, and specification. In this section, the focus is directed towards a meticulous examination of the system's intricacies, involving an in-depth analysis to identify and define its essential components. Furthermore, it delves into the process of requirements elicitation, emphasizing the systematic gathering of user needs and expectations. The subsequent phase involves the meticulous specification of these requirements, ensuring a clear and concise representation of the project's scope. Future forecasts of university population increase have been factored into our analysis of parking demand. By using in-depth analysis and simulations, we have assessed the system's ability to adjust to changing demand levels over time. Our research shows that the suggested approach is scalable, effectively meeting rising parking needs as the university population grows. Additionally, it sheds light on the chosen developmental methodology, providing insights into the structured approach adopted to guide the application's design and implementation. Through a systematic exploration of these critical elements, this chapter lays the groundwork for the subsequent phases of the development lifecycle.

A questionnaire has been conducted involving staff, visitors, and students of Taibah University to study the problem and investigate the requirements needed to in the process of development. 108 participants provided feedback on congestion and parking issues. Majority were female (66.7%), addressing concerns at the Northern gate (Female Section). 94.4% of the participants found that knowing congestion status before arrival is very useful and 44.4% of them faced difficulties finding parking at the university. This problem raised since allowing women to drive in Saud Arabia. The number has been increased and most of the students and staff use their private cars to the university rather than using transportation as in the old days. 82.4% of the participants expressed interest in knowing available parking beforehand and 83.3% believed the application would enhance security by predicting congestion times. The system outlined incorpo-

rates considerations for habits of drivers. We have conducted user research and behavioral studies to understand how drivers interact with parking system. Based on these insights, we have tailored the user interface and functionalities of the intelligent parking management system to align with driver behaviors. For example, the mobile application real-time updates on parking availability, catering to drivers' desire for convenience and efficiency. Additionally, the system employs predictive analytics to anticipate peak parking times and adjust recommendations, accordingly, taking into account typical driver behaviors during these periods.

Requirements Elicitation:

1) Functional Requirements

- Users include Faculty, Staff, Students, and Visitors.
- The system processes data from parking lot CCTV for traffic and congestion levels.

- All users can log in/log out, enter email/password, and view parking-related information.

- Admin can view/print traffic reports and manage user accounts.

2) Non-Functional Requirements

- Emphasizes usability, robustness, security, efficiency, and a fully automated system.

- Measures include a simple interface, fast updates, admin-only access, quick response times, and automation.

3) User Requirements:

- The application must be downloadable on smartphones.

- It should support monitoring free parking lots and managing reports.

- Users need to be alerted in crowded times.

Use Case Diagram:

A graphical representation of system behavior and user interaction is presented in **Figure 1**. Actors are users and include faculty, staff, students, and visitors who are benefit from the application. Users are able to view empty parking lots, view arrival time, and view gate congestion state. Admin is responsible of managing the system and reports. Key use cases include Log in, View Empty Parking Lots, View Arrival Time, View Traffic Status Reports, and View Gate Congestion State.

Use Case Descriptions:

- Log in (UC-01):

Admin logs in with email and password.

- View Empty Parking Lots (UC-02):

Users and Admin view vacant parking lots.

- View Arrival Time (UC-03):

Users and Admin view arrival times.

- View Traffic Status Reports (UC-04):

Admin views daily, weekly, or monthly traffic reports.

- View Gate Congestion State (UC-05):

Users and Admin view gate congestion state.

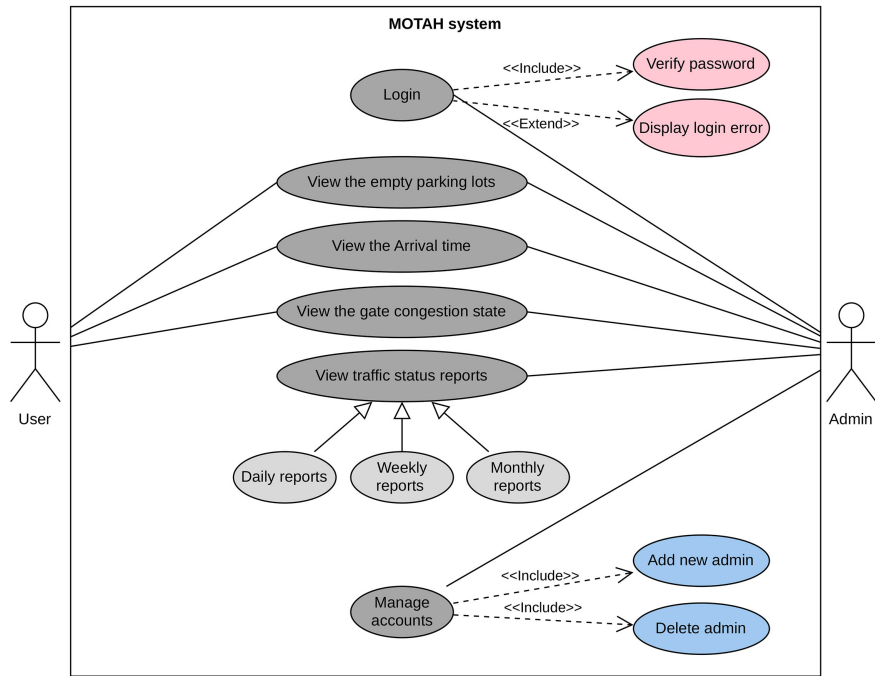


Figure 1. Motah use case diagram.

5. Developmental Methodology

In this project, Agile methodology is used because it is specifically tailored for mobile app development. As seen in Figure 2, Agile is an iterative and collaborative approach that blends customer needs with responsive solutions. It fosters growth through teamwork across various disciplines. Our plan is geared towards balancing project and product advancement while prioritizing consumer needs and overall organizational goals.

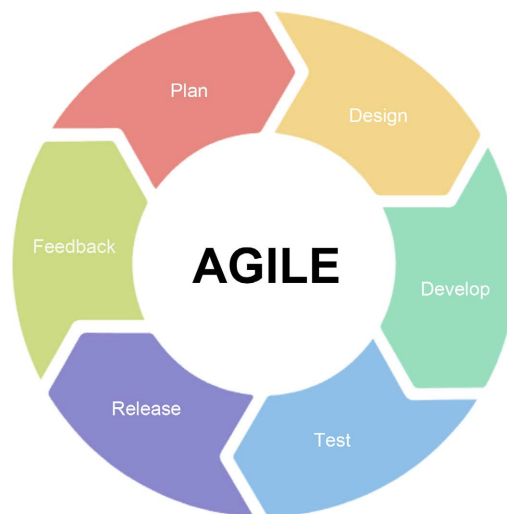


Figure 2. Agile methodology [16].

Key features of Agile methodology in the context of mobile app development include its iterative nature, allowing for continuous evaluation and adjustments. This methodology facilitates the rapid creation of high-quality software that adapts swiftly to evolving requirements for both products and adaptable initiatives [15].

The established nature of the Agile technique ensures that nearly every product and project benefits from speed and adaptability. Key tenets of Agile include:

- Prioritizing customer satisfaction by consistently delivering functional mobile applications promptly.
- Flexibility to accommodate changes in requirements, even during later stages of app development.
- Encouraging sustainable growth practices.
- Maintaining a dedicated focus on technological excellence and superior design throughout the development process.

6. System Implementation

The tools and software used for the creation, construction, and advancement of MOTAH application include programming languages such as Dart and Python. Python was primarily employed for the backend algorithm development, while Dart and Flutter were utilized for crafting the frontend components.

The app uses several packages to enhance its functionality and user experience such as: firebase, Google maps, etc. Data is gathered through a simulation model, with the database housing photos captured from the parking lot area recordings. Data collection stands as a fundamental initial phase in any project.

The algorithm underwent initial analysis targeted at processing images, particularly those depicting parking scenarios. A simulated model was devised due to the difficulty in obtaining images of the university gate and parking lots. This conceptual model played a pivotal role in the software's development. Leveraging the Roboflow Model, maintains high precision in distinguishing between different parking states. The model has an accuracy of 99.5% or more. Data is gathered and processed, facilitating the identification of available parking spaces and traffic patterns from the images. The system achieves high accuracy in identifying available parking spaces and generating reliable reports.

Additionally, our system's resource intake and implementation expenses are comprehensive, encompassing multiple components. In terms of hardware equipment, the system requires installed cameras in parking spaces to facilitate real-time monitoring and data collection. Additionally, it needs allocated resources for cloud infrastructure to support the processing and storage of parking data. On the software development front, resources have been allocated for the design and development of the mobile application interface, backend systems for data analysis and management, and integration with existing university systems. Operation and maintenance costs include ongoing expenses such as server maintenance, software updates, and technical support services to ensure the continuous operation of the system.

With aspirations for future use at Taibah university gates, we aim to further

develop this template, guided by our aspirations and efforts.

7. Results

According to the project's outcomes, the parking lot will be divided into available and unavailable spots by the Roboflow model, and the Intersection over Union (IoU) function displaying the outcome by altering the color of the boxes. The model has an accuracy of 99.5% or more [17].

Unit tests play a pivotal role in the software development lifecycle by meticulously scrutinizing the functionality of individual components within the application, including classes, methods, and functions. The primary objective of these tests is to ascertain that each component performs as intended, thereby facilitating the early detection and rectification of potential bugs. On the other hand, usability tests are designed to assess the app's user-friendliness and efficiency. Through these tests, developers can validate that users can interact with the application successfully. By identifying and addressing potential usability issues such as confusing navigation, suboptimal layout, or unintuitive interfaces, usability tests contribute significantly to enhancing the overall user experience and accessibility of the application. Together, unit tests and usability tests form a comprehensive quality assurance framework that ensures both the functional integrity and user-centric design of the application.

Overall, a comprehensive system testing approach that covers these test types can help to ensure that the Motah parking app is reliable, efficient, and user-friendly. In case: If admin enter incorrect password or forgot the password the user is allowed to reset his/her password through their email, see **Figure 3**, **Figure 4**.

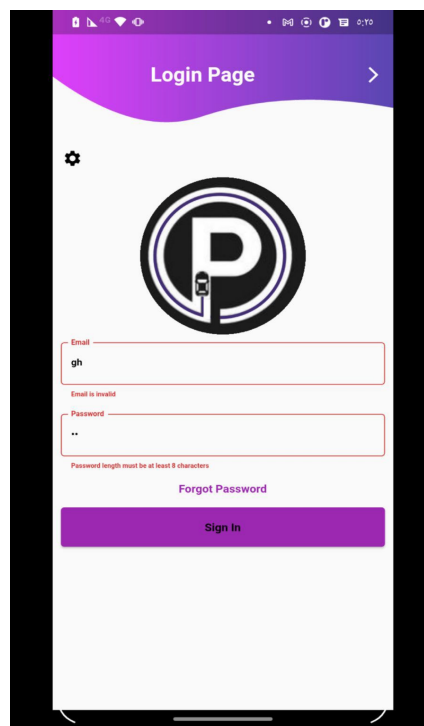


Figure 3. Testing forgot password function.

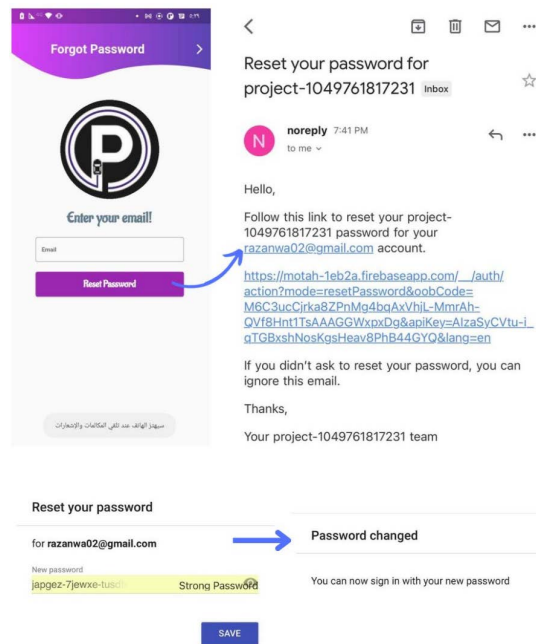


Figure 4. Resetting the Password via e-mail.

In case: If Admin Add/delete/edit users, the interface is easily drive the admin through the process of deleting or editing a user. Figures 5-8 represent the screen shots for managing users' accounts. The admin is enabled to edit or delete user accounts.

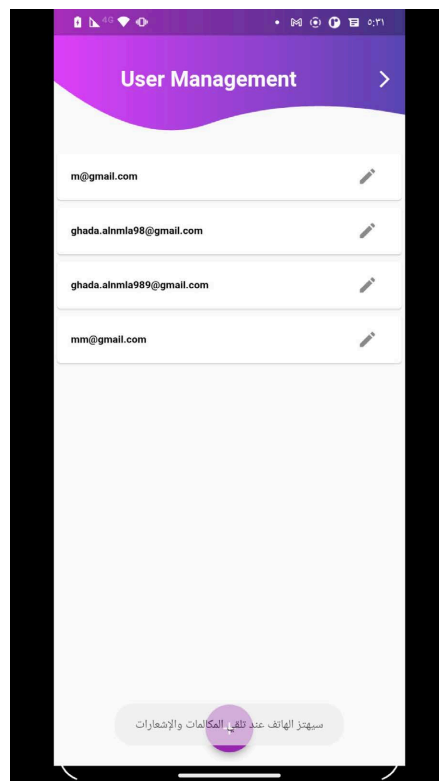


Figure 5. Testing user management accounts function.

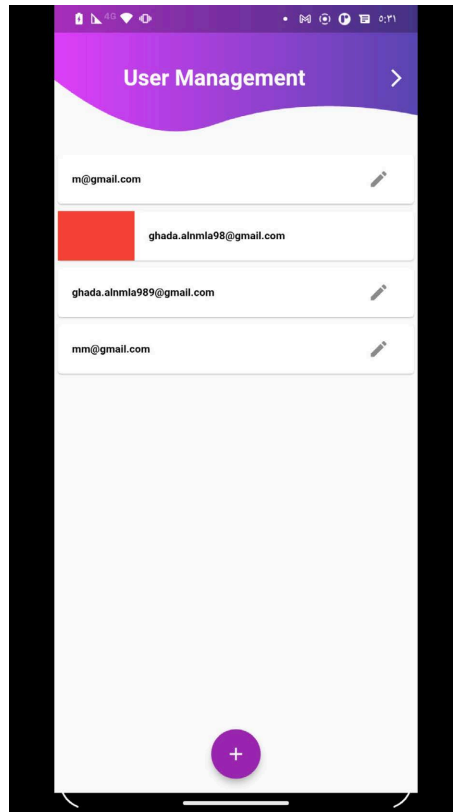


Figure 6. Add and delete/update.

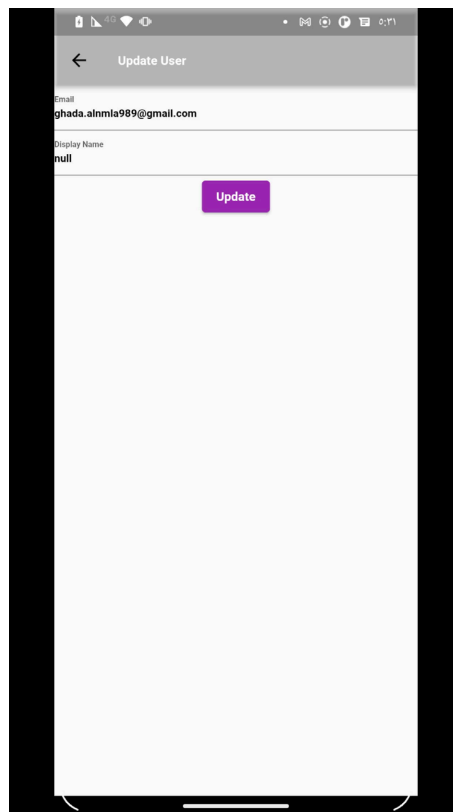


Figure 7. Delete then update.

Identifier	Providers	Created ↓	Signed In	User UID
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	zoiyaTaVw0aPshCLer0Pkavcc...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	BYlw44QTJSapX6mr9YMFenC...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	4e9KiDNweMXE5LHZIMYLCa...
razanwa2@gmail.com	✉️	Feb 16, 2023		eRvAlhD1yGe4rIBZ5YkFvkqQ...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	FdC7vMgYAmhwz7CVY6sqjR...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	eqArBjJ0odQP0EU613Bx8PH...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	8TLfWEzPxLQheqTNi9jvc1RO...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	eJ1kUL3HHLUWeqrNU303ED...
(anonymous)	👤	Feb 16, 2023	Feb 16, 2023	HBqs72mwwK2Rs76v52EaCml...

Figure 8. Updated in the databases (firebase).

8. Conclusion

Motah application is a smart parking system that was built and developed for all beneficiaries of Taibah University parking lots. It serves students, faculty members, employees, and even visitors who are suffering from the ambiguous status of the availability of free parking lots upon their arrival. This problem wastes their time, and fuel, and creates huge congestion in the gate area. This proposed system aims to help all these users by enabling incoming users to know the area density estimation. Motah assists the users with the process of finding a free parking lot without wasting their time or car's fuel. It also decreases the congestion, which facilitates the crowd management process for the university authorities.

9. Future Work

MOTAH application is currently built on Android and IOS, this can be a feature. It is commonly used all over the world. As we hope to get real authorization to apply our application to all gates of Taibah University, the following is a list of the future work and features that will improve the Motah application in the future:

- Generalizing the system so it services any organization's gates.
- Publishing the application to be available to all users.
- Enabling users to provide feedback.
- Identifying the people at the university's gates.
- Locating the car parking lot.
- Develop MOTAH application to support more languages.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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