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An Effective Approach for Smart Parking Management

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ABSTRACT

Drivers and motorists get annoyed when it takes a long time to find a vacant space in a parking lot. Looking for parking has become a headache as the number of vehicles in urban cities and the cost of land concurrently increase. There is an urgent need for innovation in smart parking systems. Currently, investors and contractors pay laborers to operate and maintain smart parking systems. Staff duties may include opening and closing gates, giving directions to drivers and motorists, and managing payments associated with the lot. This article proposes a feasible, dependable, and smart algorithm for managing a parking system. This algorithm utilizes image processing techniques to provide real-time data. No labor is required to operate and handle the system. The system itself automatically handles all operations except maintenance. Furthermore, this algorithm is more cost-effective than other similar systems and equally effective. Numerous simulation scenarios were carried out on MATLAB to verify its developed approach. A comparison evaluation juxtaposes the proposed approach with other solutions in the literature. This evaluation clearly indicates that the presented method outperforms other solutions in terms of technologies being used, devices being utilized, and cost.

1. INTRODUCTION

Smart cities were once only imagined in science fiction movies, but recently, the dream of building smart cities has become possible with evolving technologies. These smart cities utilize different technologies to provide civic services and solve problems. They are data-driven, meaning smart cities collect and analyze data to create and implement real-time solutions. Figure 1 depicts a general perception of the characteristics of a smart city.

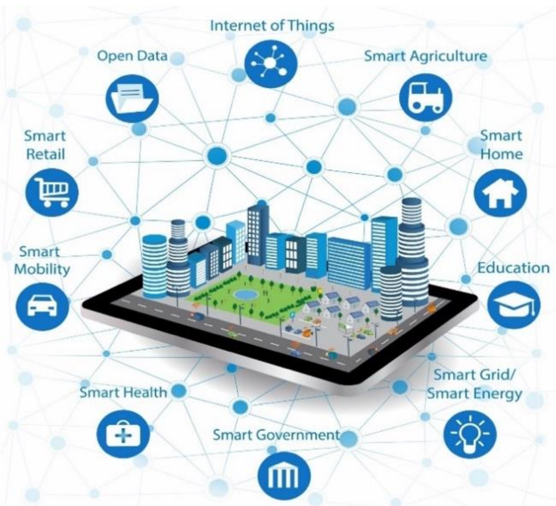


Figure 1. Concept of the smart city [1]

Each smart city uses a different framework based on their data and communication technologies to provide government services, public services, and municipal services [2, 3]. One common trait, however, is an intelligent network of connected devices that allows a city's function to be data-driven [2, 4, 5]. These connected devices create a sustainable city. The technologies that resident's access through smartphones and hand-held devices can make cost-of-living more affordable, improve the quality of life, and provide more efficient solutions and services when properly programmed [6-10].

While some governments, like those in Barcelona and New York, have implemented numerous technologies to transform traditional cities into smart ones, others have started building new cities based on smart city models. Neom, Saudi Arabia is one such smart city. Figure 2 illustrates a proposed view of Neom by the end of 2030 taken from the Saudi government's Vision 2030. The expected budget for building this city exceeds 500 billion dollars. Currently, different companies have initiated their works in Neom, and the infrastructure is expected to be ready for residents by the end of 2024. The cost is worth it. In New York City, the authorities save billions of dollars every year by placing different smart solutions such as smart grids for electricity, Wireless Network Sensors (WSNs) for parking lots, and smart garbage solutions. Every smart city utilizes different technologies to:

1) Improve the safety and security of the residents.
2) Attracting companies to invest in order to increase the growth of the economy.
3) Make the surrounding environments more efficient.

4) Provide numerous municipal services through different technologies.

Figure 2. Fictional view of Neom city [11]

In big cities such as London, Paris, and New York, finding vacant spaces to park vehicles is a big problem. Drivers and motorists are forced to spend a long time searching for a spot near their offices, hotels, or shopping centers. As the number of vehicles increases daily, this problem gets bigger and bigger. Authorities should look for alternative solutions. Many technology service providers suggest different real-time solutions to overcome this issue based on several technologies. One such technology, the Internet of Things (IoT), is depicted in Figure 3. Practical and consistent smart car parking systems have become essential and crucial. Various solutions for smart car parking systems have been developed to utilize all parking spaces efficiently and successfully while the cost of labor [5-8]. That said, municipal governments should consider the cost of systems as well.

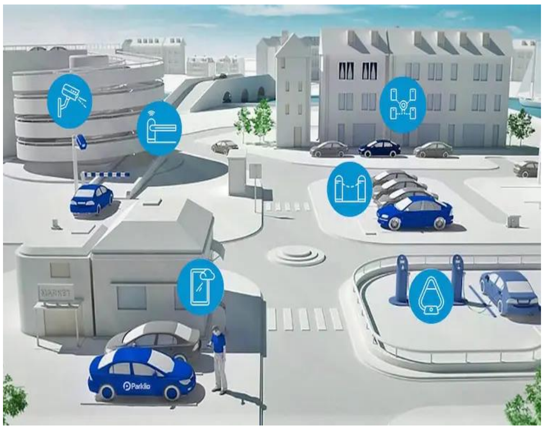


Figure 3. Sample of car parking systems using IoT technologies [12]

This manuscript develops and presents an automated and efficient smart car parking approach that can be easily managed and maintained. This algorithm is cost-effective. It just requires a camera to provide real-time data through images or video streams of the considered parking area. These images or video streams are processed to identify the total number of vehicles that occupy spaces in the parking area and to verify whether vacant spaces exist or not. After that, the electronic devices direct drivers or motorists to the vacant spaces available. Details about the presented and developed system are provided in Section 3.

The rest of this paper is organized as follows: Section 2 contains related works and Section 3 provides details about the proposed method. The discussion and results are presented in Section 4, and Section 5 concludes the paper.

2. RELATED WORK

Dhamane et al. [2] proposed a smart parking system based on an IoT technology. It used an ultrasonic sensor to detect vacant spaces and vehicles. A web application was utilized to display a real-time message about the status of parking lots. Drivers and motorists could utilize their mobile phones to search for vacant spaces prior to their arrival. The system reduced fuel consumption, air pollution, and the time needed to look for vacant spaces. However, the proposed approach in this manuscript is more cost-effective than the system proposed by Dhamane et al. since it requires no human labor to operate it and utilizes only one camera to provide real-time data. Additional features such as a metering system are easily integrated into this paper's method with no hidden cost.

Waqas et al. [3] developed a smart parking management system using an image processing technique. This system used one of the image processing algorithms to mark virtual vacant spaces in parking lots to extract information about vacant and occupied spaces. This information was utilized to guide the incoming drivers or motorists towards vacant spaces. This method contained two interfaces, one for vehicles and one for administration. The authors intended to use their system in areas where there were no such systems. This system consumed much time processing data since it drew imaginary lines for a considered parking lot and identified vehicles whether they were parked correctly or not. The proposed algorithm herein is faster since it just detects the number of vehicles in the parking areas and the number of vacant spaces.

Sulthana and Badu [5] developed and implemented a real smart parking system based on an IoT methodology and on-site deployment. A Global Positioning System (GPS) and a Global System for Mobile communication (GSM) were utilized to track vehicles. An Android application, wireless network sensors, and an active RFID were used to control and manage gates. A Raspberry Pi device was used to control all operations. The different components installed and utilized make this system quite costly, but our proposed system is very cost-effective. Its cost is almost nothing since it uses one camera. No sensors are required. Readers can refer to Sulthana et al. for additional information.

Chougula et al. [7] implemented an automatic smart parking and reservation system based on IoT technology. This system was controlled by an Android application to lower human intervention. In addition, a web application was developed to help drivers or motorists book vacant spaces prior to their arrival using either a PC or a smartphone. Furthermore, an Arduino microcontroller, a Database (DB) server, an RFID, and a WIFI module were utilized in this system. These components render this approach costly, not unlike those proposed by Sulthana et al. The additional functions it offers that send notifications and offer a metering module are easily integrated into our proposed system.

Elsonbaty and Shams [8] implemented a smart parking management system that depended on some Arduino components, an Android application, and an IoT methodology. IR sensors were used to validate vacant space data and transmit this data through a communication module. An IoT technology was involved to track available locations through a wireless connection. This system requires several parts to perform the desired functions. One of its drawbacks was that since its services depended on the internet, the system could be completely off if no internet connection was detected by the system. Our presented system requires no internet service as the captured images or video streams are fed directly to a host machine through a direct connection media.

Satyanarayana et al. [13] developed an advanced smart parking system using an IoT technology. The technology identified vehicles and showed the number of vacant spaces at an entrance gate of the parking lot. In addition, it provided a shortest path from the entrance gate to a vacant space and gave directions to users through a display media. An Optical Character Reader (OCR) and IR sensors were used to capture vehicle plate numbers. This approach is similar to our proposed system. However, the presented method herein is more cost-effective compared to the implemented system proposed by Satyanarayana et al. given the use of the single camera instead of sensors. Interested readers can refer to Satyanarayana et al. for additional information.

Mangwani [14] developed a smart parking system based on an IoT method. This system utilized the IoT approach that enabled drivers to monitor and book vacant spaces. It used a sensor in every parking slot to send data to a central controller in a server. It used the internet service to provide real-time information to drivers. This system could become very costly if the parking area was huge since every parking designated space required a sensor to be installed in it. The cost of the presented approach, in contrast, can be less than $100 for any size parking lot.

Bhoyar et al. [15] developed a smart parking system based on an IoT technology and cloud computing as well. This system claimed to increase the efficiency of an existing cloud-based smart parking system by developing a new network architecture using the IoT technology. Using this system, drivers could search for vacant spaces by utilizing a paid service. This paid service considered parking lots within a determined radius from a driver and displayed the number of available vacant spaces near him or her. Wireless sensor networks, IoT technology, and an RFID were utilized in the implemented system. The authors provided no information about experiments conducted to test and verify their system. In addition, their system was costly since numerous WSNs, RFIDs, and IoT technologies were involved along with a cloud server and a web application. As stated, the proposed system only requires one camera. No other tools are used unless there is a need to integrate this approach with additional features or systems, such as notification delivery for drivers who parked their vehicles in the parking lots.

Jawad et al. [16] designed and implemented a smart car parking system. It sent signals to either open or close gates according to the status and conditions of a considered parking lot. In addition, it worked based on a piezoelectric sensor, which detected the weight of vehicles. An Arduino microcontroller was used to control all operations along with a seven-segment display. The proposed algorithm is more cost-efficient than the developed system proposed by Jawad et al., given its minimal need for equipment.

3. THE PROPOSED SYSTEM

The proposed system uses numerous image processing and segmentation techniques in its operations. It is smart since it requires no human intervention at all to run its operations. In addition, these operations are fully automated. Furthermore, several filters are utilized as well to either remove the noise or improve the quality of captured images or video frames from live video streams. Figure 4 illustrates components of the proposed and presented system.

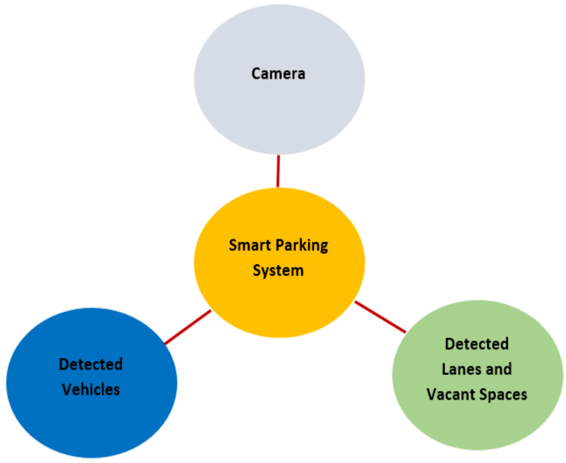


Figure 4. Components of the proposed system

The components in Figure 4 can be added to depending on the requirements and needs of the user. Additional hardware can be easily added upon request.

The presented algorithm provides several benefits, summarized as follows:

i. Removes human labor cost.
ii. Reduces air pollution.
iii. Provides a sustainable environment.
iv. Increases the parking revenues.
v. Being environmentally friendly.
vi. Automates all operations.
vii. Enhances drivers' experiences.

Figure 5 depicts a flowchart of the developed and implemented system.

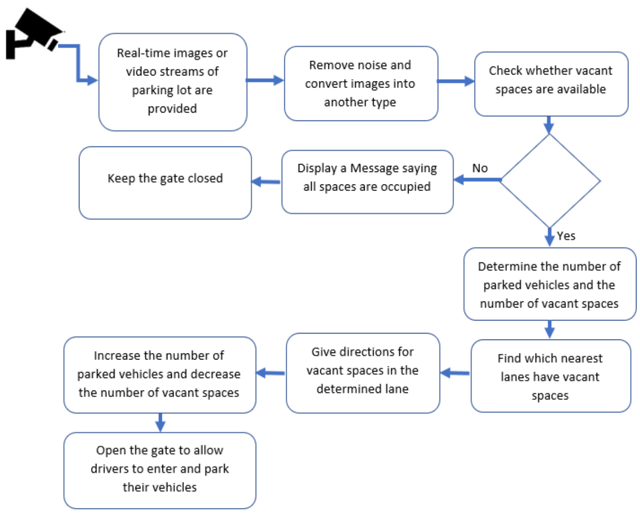


Figure 5. Flowchart of the proposed approach

The system starts by receiving real-time images or video streams from the installed camera, which is directly connected to a machine through either a coaxial cable or a fiber cable. The connection medium depends on the requirements of the parking lot since the fiber cable provides more data transmission in less time. If the camera sends images, then these images are processed one by one. Otherwise, video streams are processed frame by frame and converted into frames using a built-in function in MATLAB.

The second step is the preprocessing stage in which noise is removed and the quality of the captured image or video frames is enhanced. Then, this data is converted into grayscale. This process prepares data for the processing and segmentation techniques.

The next step performs the utilized processing and segmentation methods in MATLAB using numerous functions. These functions require some toolboxes to be already installed and run in a host machine. In this stage, the captured images or frames are resized based on the size of the parking lot. Then, a matrix of two dimensions dependent on the size of the utilized images or video frames is created. Outputs from this stage are used to determine the number of vacant spaces, the number of already parked vehicles, and the lanes where these vacant spaces are located. The processing and segmentation techniques detect vehicles in the designated parking area, determine the total number of available spaces, and assign it to a parameter (a). Then, a threshold parameter (b) is assigned to the obtained number of detected vehicles in the parking lot. The equation to compute the number of vacant spaces parameter (C) in the parking lot is:

$$C = a - b \tag{1}$$

If the value of C is 0, then, it means the parking lot is full. In this case, the proposed algorithm keeps the entrance closed and displays a message to inform drivers or motorists about the status and conditions of the parking area. When C is > 0, then, the system determines which nearest lane has vacant spaces available. This lane is given to drivers or motorists along with directions to that lane. The presented system then opens the entrance gate.

The determination of the lane is performed using the processing and segmentation approaches. The number of vacant spaces in the determined lane is computed using processing and segmentation methods that determine how many vehicles are parked and the total number of vacant spaces in the determined lane. Both values are assigned to variables (d) and (e) respectively. The following equation is used to compute the total number of vacant spaces (F).

$$F = d - e \tag{2}$$

After a vehicle enters and parks, the algorithm decrements the total number of vacant spaces and increments the total number of parked vehicles as follows:

$$F = F - 1 \tag{3}$$

$$b = b + 1 \tag{4}$$

The pseudo code of the proposed system is as follows:

Algorithm: Smart Parking and Management System

Input: Real-time images or live video streams.

Output: Number of parked vehicles, nearest lane to the drivers or motorists, number of vacant spaces and directions to these spaces.

1. Scan the parking lot every time a vehicle enters or leaves.
2. If no vacant spaces are available, then:
3. Display a message to inform drivers and keep gate closed.
4. Else.
5. Remove noise from captured image.
6. Transform the resultant image into a gray image.
7. Determine the dimensions of the parking area.
8. End of Preprocessing phase.
9. Assign the total number of parked vehicles to the threshold variable.
10. Subtract captured image of current parking area from the parking map structure.
11. For i = 1: length of parking area
12. For j = 1: width of parking area
13. Do the following:
14. Find resultant image from subtraction process and compare it with the threshold.
15. If result > threshold, then:
16. Place 1 in the current index,
17. Else.
18. Place 0.
19. End // refers to the if statement.
20. End // refers to the inner loop.
21. End // refers to the outer loop.
22. Check which lanes have vacant spaces to, choose the nearest lane to direct drivers to it.
23. Compute the total number of vacant spaces in the determined lanes.
24. Open the entrance gate.
25. Display instructions for them to park.
26. Decrement the total number of vacant spaces.
27. Increment the total number of parked vehicles.
28. End of algorithm.

4. RESULTS AND DISCUSSION

Several simulation experiments were conducted in MATLAB to validate all of the operations and verify the correctness of the workflow of the proposed system. These experiments were carried out on MATLAB R2017b which runs on any machine that uses Windows as its operating system. This version of Windows is Windows 11 Pro. This machine's specifications include an Intel chip of 8th generation of i7, 2 GHz of the clock pulse, and 16 GB of RAM. In addition, it is a 64-bit based system.

A free built-in software in Windows is utilized to draw the images for the simulation experiments. In these images, a vehicle is represented by X, as illustrated in Figure 6, which shows a general parking lot with 3 lanes and 2 gates, one for entry and another for exit. This parking lot accommodates a maximum of 40 vehicles. The presented algorithm produces 3 subgraphs when the parking lot reaches its maximum capacity and 4 subgraphs when vacant spaces are detected.

Two scenarios were conducted using the drawn images from the software. Scenario 1 represents the parking lot when 40 vehicles are parked in it, meaning it has reached capacity, and there is no place for a new vehicle. Scenario 2 refers to the same parking lot when it holds 24 vehicles.

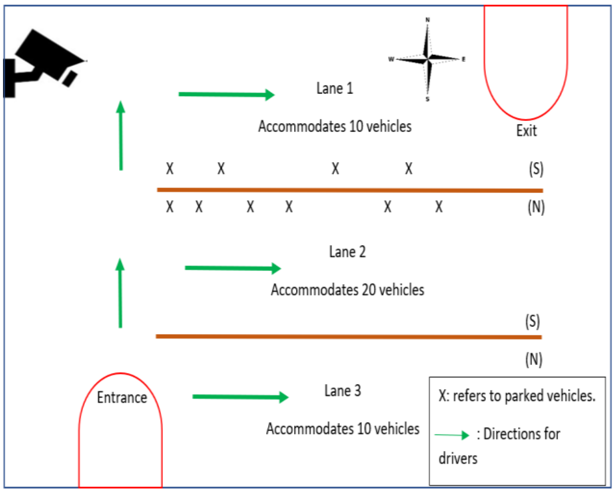


Figure 6. Considered structure of the parking lot

Scenario 1

Figure 7 depicts the parking lot at full capacity with no vacant spaces. In this scenario, drivers are instructed to look for alternative parking areas. This Figure includes 3 subgraphs that represent the obtained outputs from the proposed system. The display message is also included in the Figure.

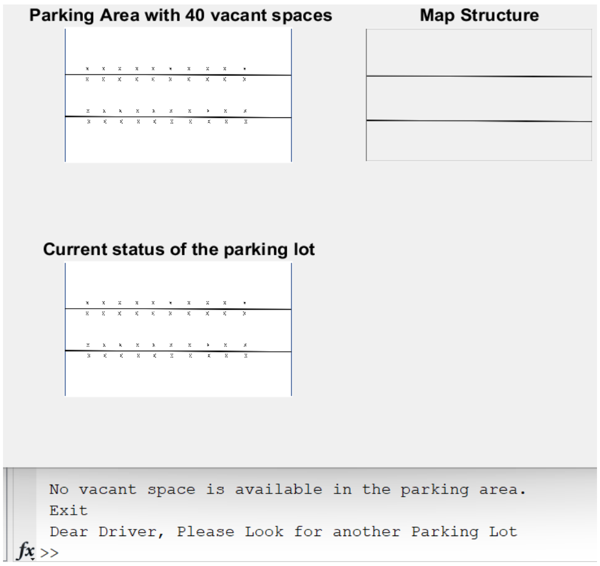


Figure 7. Outputs of the proposed system for Scenario 1

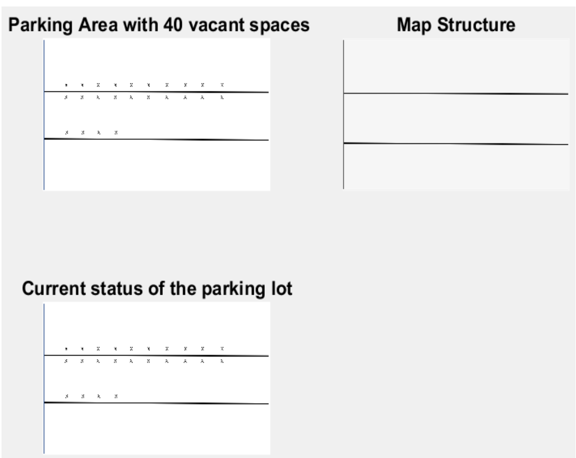
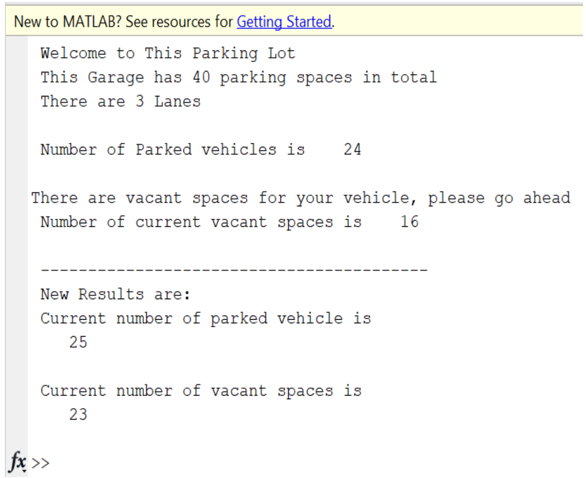


Figure 8. Outputs of Scenario 2

Scenario 2

Figure 8 illustrates the obtained outputs from the proposed approach. It shows that the parking lot is occupied by 24 vehicles and 16 vacant spaces are available. Figure 9 depicts the obtained numerical values from the presented method.

For Scenario 3 and Scenario 4, two images of real parking areas were downloaded from Google, links for which are available in [17, 18]. Scenarios 3 and 4 demonstrate the system's usage in real parking areas with vacant spaces.



```
New to MATLAB? See resources for Getting Started.
 Welcome to This Parking Lot
 This Garage has 40 parking spaces in total
 There are 3 Lanes

 Number of Parked vehicles is    24

There are vacant spaces for your vehicle, please go ahead
 Number of current vacant spaces is    16

 -----------------------------------------
 New Results are:
 Current number of parked vehicle is
     25

 Current number of vacant spaces is
     23

fx >>
```

Figure 9. Numerical results of Scenario 2

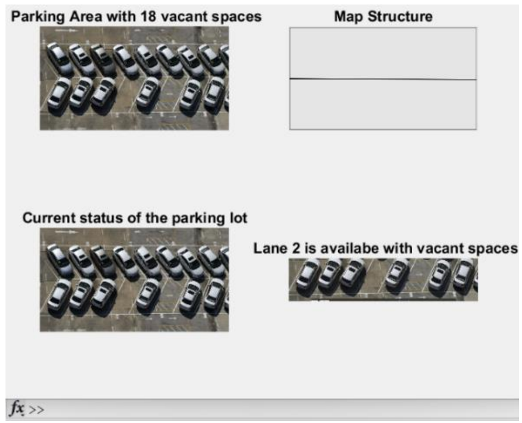
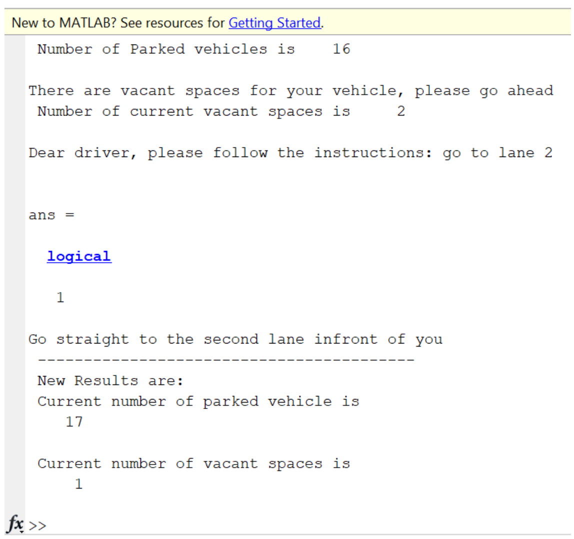


Figure 10. Outputs of Scenario 3



```
New to MATLAB? See resources for Getting Started.
 Number of Parked vehicles is    16

There are vacant spaces for your vehicle, please go ahead
 Number of current vacant spaces is     2

Dear driver, please follow the instructions: go to lane 2


ans =

  logical

   1

Go straight to the second lane infront of you
 -----------------------------------------
 New Results are:
 Current number of parked vehicle is
     17

 Current number of vacant spaces is
      1

fx >>
```

Figure 11. Numerical results of Scenario 3

Table 1. Comparative evaluation results

Works	Evaluation criteria			
	Methodology	Accuracy	Utilized equipment	The cost
Dhamane et al. [2]	IoT	Not mentioned	Arduino, Radar, GSM sensors, cloud server, Android application and Wi-Fi module	costly
Waqas et al. [3]	Image segmentation and preprocessing	Not mentioned	Camera, web server, DB server, and internet service	costly
Sulthana & Badu [5]	IoT	Not mentioned	GPS, GSM, WI-FI module, Raspberry Pi, IR sensors, ultrasonic sensors, LED lights	costly
The Proposed System	Image segmentation and preprocessing	> 96%	One camera only	very cheap

Scenario 3

A real parking lot with an 18-vehicle capacity is depicted in Figure 10. Two vacant spaces are shown available. The obtained results from the presented system are included. Figure 11 shows the obtained numerical results after applying the presented algorithm.

Scenario 4

Another real parking lot is shown in Figure 12, Figure 13 refers to the obtained numerical results of Scenario 4.

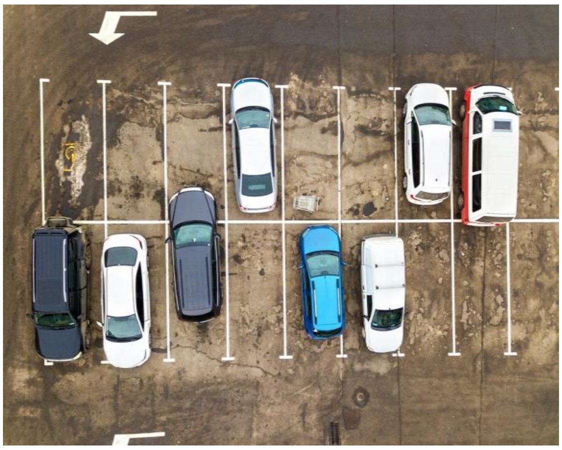


Figure 12. Second real parking lot

As shown in all 4 scenarios, the proposed algorithm successfully managed all possible scenarios and produced perfect results. The presented and implemented system in this manuscript is very cost-effective since it just needs one camera to operate and produce its outputs. Other developed works in the literature discussed above detect vacant spaces with IoT sensors, which are more costly. In contrast, the presented method herein costs almost nothing since the CAMs are very cheap. The expected price for a camera with a high-quality lens and focus is less than $20. These alternative approaches also depended on internet or WIFI services to operate and function properly. This is a drawback: If any of these services went down for any reason, the operations would be negatively affected and even unavailable for a period of time. In contrast, the proposed algorithm in this paper requires no internet or WIFI service to operate as the CAM is directly connected to the operating machine. This ensures that there would be no service unavailability unless the running machine goes down for unexpected reasons. Even in such an instance, the proposed method is still more viable than those presented approaches in the literature. Table 1 demonstrates the comparative evaluation results between the proposed system in this article with some works from the literature in terms of methodologies employed, accuracy, utilized equipment, and the cost.

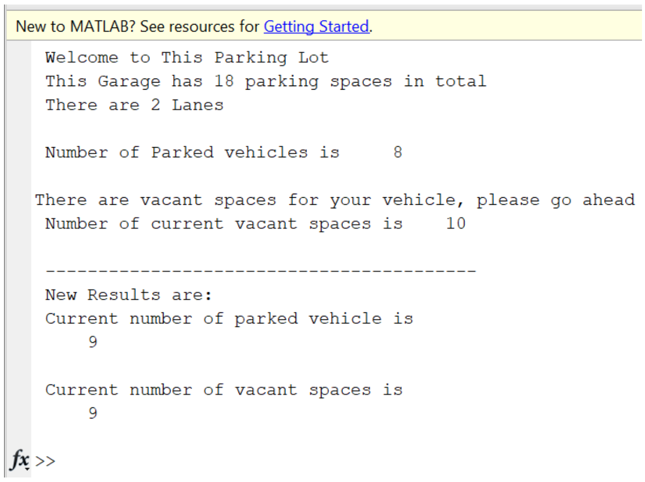


Figure 13. Numerical outputs of Scenario 4

5. CONCLUSION

The implemented system in this article is highly useful as proved by the outputs of the presented scenarios. It is easy to operate, maintain, and utilize anywhere. In addition to the parking services, a smart metering system can be easily incorporated into the system to determine a payment rate for drivers accessing the parking lot. The integration of a notification system for drivers or motorists is also possible with some adjustments. MATLAB is used to validate the proposed method, and its results show that the proposed algorithm performs as intended and produces accepted outputs.

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