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A Transfer Learning Approach for Real-Time Parking Availability Classification Using MobileNetV2 and Efficient Net

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Abstract: It is hard for computers to tell if parking is available because of things like different parking lot layouts, different types of vehicles, and photos that are low quality or grainy. We propose a transfer learning method based on TensorFlow Hub to create a large-scale multi-class image classification system for determining whether a parking space is available. To improve the model's performance, pre-trained architectures such as MobileNetV2 and Efficient Net are utilised to create rich feature representations from images of parking lots. We utilise a publicly available dataset with annotated images of parking lots and cars for training and testing. To improve the quality and reliability of the data, various preprocessing methods are employed, including image scaling, normalisation, and augmentation. We use categorical cross-entropy loss to improve the model, and we evaluate it using Top-1 and Top-5 accuracy metrics. The results demonstrate that this method is effective and can be applied in real-time parking availability detection, smart city solutions, and automated parking management systems. We also examine problems, including class imbalance, vehicles blocking each other, and misclassification, as parking layouts are identical. This work demonstrates how transfer learning can be beneficial for classifying large numbers of images, particularly for use on edge devices and in real-time applications that track parking availability.

Keywords: Mobilenetv2, Efficient Net, Image Scaling, Normalisation, Augmentation, Real-Time Monitoring, Internet of Things

Introduction

In a world that is rapidly becoming more urban, the number of cars is increasing at an alarming rate, making parking spaces one of the most significant challenges that modern cities face [51]. Urban infrastructure is struggling to keep pace with the growing demand for parking as the number of individual and commercial vehicles continues to increase [70]. Because there aren't enough parking places, drivers get frustrated every day, and urban traffic management systems don't work as well as they could. In cities and other densely populated areas, drivers often spend a significant amount of time searching for a parking spot by driving around parking lots or city blocks [60]. This attitude not only causes problems and delays but also contributes to larger societal issues, such as traffic congestion, increased fuel consumption, and environmental pollution. The lack of a smart, real-time, and centralised parking management system exacerbates these problems [67]. This makes things harder for both drivers and the parking authority. This experience would be much better with a smart parking management system that can track, forecast, and notify users in real-time when parking spots are available [79]. This would reduce the time spent searching for spaces, optimise parking usage, and enhance overall urban mobility.

The problems with traditional parking systems come from the fact that they are manual and don't change [73]. Most cities manage parking spaces with either physical attendants or traditional ticket-based systems. These systems don't give drivers or administrators real-time information

[86]. This means that drivers often don't know if a spot is open or where it is when they pull into a parking lot. Due to this ambiguity, people often drive around in parking areas, wait longer, and become frustrated [78]. Additionally, these systems cannot dynamically set prices, utilise predictive analytics, or intelligently allocate slots, which could help better balance parking demand and availability [50]. The total effect of these problems is significant: drivers spend time, fuel, and endure stress, all of which contribute to pollution and traffic congestion in cities [59]. This issue is not exclusive to major metropolitan areas; it is also manifesting in smaller towns and semi-urban locales where vehicle ownership is increasing.

This study presents a comprehensive smart car parking management system that leverages Internet of Things (IoT) technology, real-time data processing, and mobile application interfaces to deliver a seamless user experience [80]. The suggested system utilises current sensors, wireless connections, and cloud computing to establish a networked infrastructure that can determine whether each parking space is full or empty [55]. The data collected is sent to a central platform, where it is processed and made available to users through a dedicated mobile app. With this app, users can view real-time parking availability, reserve spots in advance, get directions to their chosen parking location, and make secure digital payments [74]. The system provides a comprehensive solution to the growing parking problem by integrating hardware components, such as ultrasonic or infrared sensors, with software elements, including mobile app interfaces and cloud-based databases [91].

Not only do drivers gain from this kind of system, but so do parking authorities, city planners, and municipal governments [66]. Being able to verify parking availability before arriving at a site makes life much easier for drivers and cuts down on the time they spend searching for spots [71]. The device simplifies parking officials' tasks by automating the monitoring process and reducing human errors. Planners in cities may also use the data from the system to make informed decisions about building new infrastructure, such as determining where parking lots will be needed in the future or where there is a high demand [68]. The system's data analytics component can also enable dynamic pricing models, which help optimise the use of available spaces and alleviate congestion during peak times. The proposed smart parking management system is based on the integration of several new technologies. The primary function of IoT sensors is to determine whether each parking space is occupied or available [63]. Each location has these sensors, which can detect the presence of a car. Depending on how the infrastructure is set up, the gateways utilise Wi-Fi, LoRa, or GSM technologies to wirelessly transmit data from these sensors to a central server. Then, the server processes this data and updates the database in real time [81]. Users may then access it using a mobile app interface. The smartphone app is the primary means by which users interact with the system. It allows them to view available slots, book a spot, locate the parking location, and pay.

For real-time updates, the hardware (sensors), software (mobile app), and database (cloud server) must be able to communicate with each other seamlessly [90]. If there is any delay or data loss, the availability information could be wrong, which would make users less likely to trust the system [54]. Because of this, the project emphasises the use of reliable communication protocols, methods for identifying and resolving errors, and techniques for synchronising data efficiently. The system is also designed to be scalable, which means it can add thousands of sensors in various locations without slowing down [69]. Because it can be scaled up or down, the system can be utilised in various settings, ranging from small commercial parking lots to large public parking facilities in cities.

The mobile app component is particularly important for the ease of use of the system. The design prioritises ease of use, accessibility, and functionality [61]. When you open the app, you get a map-based interface that shows local parking lots and colour-coded signs of slot availability: green for available, red for occupied, and yellow for reserved [77]. Users can select a facility, view its details such as price, distance, and available spots, and then reserve a spot. Once a spot is booked, the app uses built-in GPS services to give directions to the exact location of the parking space. The app not only helps you find your way, but it also has secure payment gateways that enable you to pay with credit cards, debit cards, or digital wallets [87]. This eliminates the need for cash transactions and makes the parking process even easier. A management portal for administrators is another important part of the proposed system [48]. The parking authority can use this portal to monitor occupancy levels, generate reports on usage, manage bookings, and receive maintenance alerts from the sensors [72]. The site provides managers with useful information about how people use the service, enabling them to make informed decisions based on data, such as adjusting prices or adding more parking spaces in areas with high demand [89]. Analytics also lets you develop prediction models, which assist officials in planning for spikes in demand during events, weekends, or holidays [82].

It's also important to discuss how the system impacts the environment [53]. The method directly helps reduce carbon emissions and fuel use by cutting down on the time drivers spend idling or circling in search of parking spots. Research indicates that a considerable fraction of urban air pollution is derived from automobiles idling in traffic or seeking parking [75]. Therefore, utilising a smart parking management system benefits both users and managers, and it also supports broader environmental objectives. Additionally, as more people become interested in building smart cities, these technologies align with global initiatives to establish smart and environmentally friendly city infrastructure [83]. The proposed system's dependability and performance are highly contingent upon the resilience of its foundational technologies. For example, IoT sensors must be robust and able to withstand the weather so they can function effectively in outdoor environments [64]. There should be minimal delay in the communication network so that data can be sent in real-time.

Additionally, the mobile app must function smoothly on various devices and operating systems, allowing everyone to utilise it. Another important consideration is data security [56]. Because the system stores user data, location information, and payment information, it needs to utilise robust encryption and authentication methods to prevent data breaches and unauthorised access.

One of the best features of the system is that it can be used in a variety of ways. It can be used in shopping malls, hospitals, office buildings, airports, commercial complexes, and on-street parking in cities [84]. You can modify each implementation to suit your specific needs. For example, an airport deployment would focus on long-term parking with the opportunity to reserve ahead of time. In contrast, a mall deployment might focus on managing short-term parking and rapid turnover. In all cases, the system's modular design enables the addition or modification of functionality without impacting its current operation [52]. There are significant economic effects of implementing such a system. By automating the parking management process, costs for labour, tickets, and manual monitoring decrease.

Additionally, parking operators can increase their revenue by optimising the use of their parking spaces. The system can provide cities with useful information on how cars move and how much parking is required [57]. This information can be used to make upgrades to the infrastructure or implement congestion-reduction measures [76].

The social effects are just as important as the technological and economic ones. Drivers are less stressed, have shorter wait times, and are happier with urban transit services [62]. Better parking management benefits local governments and companies by enhancing traffic flow, reducing congestion, and enhancing their public image. When this system is integrated into larger smart city frameworks, it can yield synergistic benefits that not only improve parking but also enhance public transport coordination, road safety, and overall urban mobility [88]. The rapid rise in the number of cars and the resulting lack of parking places is a growing problem that requires innovative technical solutions. The smart car parking management system proposed in this paper is a comprehensive solution that leverages IoT, real-time data processing, and mobile app development to effectively address this issue [49]. The technology makes parking easier by providing users with real-time updates on parking availability, the ability to make reservations, and secure payment options [85]. This reduces traffic congestion and enhances the user experience. It helps not only individual drivers but also the city as a whole by making it more efficient, environmentally friendly, and economically viable [65]. As cities become increasingly smart and networked ecosystems, technologies like these will have a growing impact on how people navigate cities in the future [58]. As technology continues to improve and smart city frameworks become more common, intelligent parking solutions will help make cities cleaner, safer, and more efficient, which is what modern living needs.

Methodology

We The creation of the Vehicle Parking Availability Monitoring and Efficient Management System with App follows a set plan. The project begins with a thorough examination of the requirements to determine what both users and system components need. Next, the system architecture is designed [93]. This includes the sensor network for monitoring parking spaces, the backend infrastructure, and the mobile app interface. Then, IoT-based sensors, such as ultrasonic or infrared sensors, are installed in each parking space to detect the presence of a car [101]. These sensors send real-time data to a central server over Wi-Fi or another compatible communication protocol. The microcontroller connects them [97]. At the same time, a mobile app is being developed that will provide users with capabilities such as real-time slots.

The paper is structured methodically to provide a thorough understanding of the Vehicle Parking Availability Monitoring and Efficient Management System with an App [99]. The first chapter talks about the project, including its background, importance, issue description, goals, scope, and area of study. It provides the reader with a foundation to understand why the system was created and what its objectives are. The second chapter provides a comprehensive overview of the literature, highlighting previous work and current technologies in the field of smart parking systems [95]. It examines the pros and cons of past methods and explains why the proposed system is necessary. The third chapter is all about analysing and designing the system [100]. It discusses requirement specifications, system architecture, and data flow diagrams, and provides a comprehensive description of the hardware and software components used in the project.

This project aims to design and build a smart parking system that utilises IoT technologies and a mobile app to efficiently monitor and manage parking spaces [98]. With a simple app, the system enables customers to view real-time parking availability, book spots in advance, navigate to their designated parking spot, and make digital payments[92]. This method reduces the time it takes to find a parking spot, eases traffic congestion, and makes getting around the city easier overall. The chapter also includes a problem statement, which addresses the primary issues with parking inefficiencies and the absence of real-time monitoring [96]. The project's goals are outlined, with a focus on delivering a solution that is reliable, scalable, and user-friendly. We discuss the project's scope to establish limits and regions where it can be applied, such as shopping malls, office buildings, and public parking lots [94]. The project's domain is also specified, highlighting its importance in smart transportation, the Internet of Things (IoT), and the creation of mobile applications.

Literature Review

This research introduces an IoT-enabled smart parking framework designed to optimise the management of urban parking facilities. The system utilises a network of sensors that are interconnected to detect the presence of a vehicle in real-time and transmit that information to a central platform. The system can identify empty spaces, reduce the time drivers spend searching for parking, and maximise space utilisation by continuously monitoring the situation [9]. The authors emphasise that responsiveness, reliability, and scalability in real-time are crucial design elements. The system architecture has sensors, gateways, and a cloud server that stores and processes data. Users can access real-time parking information, book spots, and receive assistance with directions through a smartphone app. The proposed method utilises IoT infrastructure to reduce traffic, fuel consumption, and pollution, while also enhancing the user experience and operational efficiency [34]. The paper shows how IoT could change static parking systems into smart, adaptable, and environmentally friendly solutions for cities.
This work concentrates on the utilisation of deep learning models to forecast real-time parking availability and mitigate traffic congestion in metropolitan environments [35]. The suggested solution combines advanced neural network architectures to analyse traffic patterns, sensor data,

and historical occupancy trends to predict parking demand. The framework combines computer vision methods and time-series prediction models to make predictions more accurate in changing situations [21]. By combining these predictive analytics with mobile communication platforms, drivers can receive real-time alerts on when parking spaces are expected to become available, which reduces unnecessary car movement. The authors emphasise that forecasting traffic flow and urban mobility efficiency is more important than merely observing them [45]. The method also helps reduce fuel consumption and environmental harm. The study demonstrates how deep learning facilitates proactive parking management, converting reactive parking searches into strategically planned and optimised operations that align with the objectives of smart city infrastructure.

This study investigates the creation of an intelligent parking management system utilising wireless sensor networks [25]. The technology utilises sensors spread across parking lots to monitor the number of cars parked and transmit the information wirelessly to a central control unit. The communication between sensors and computers enables real-time tracking of accessible spaces, which users can access through a digital interface. The study's primary objectives are to enhance monitoring accuracy, reduce communication delays, and ensure the system's scalability [36]. The proposed architecture is well-suited for large-scale use, as it utilises energy efficiently and can handle faults effectively. The solution eliminates the need for manual supervision and reduces driver frustration by automating the identification and reporting of parking status [1]. The work demonstrates how sensor-based technologies can be a key component of intelligent transportation systems. They can be used to build smart, data-driven urban parking infrastructure, making better use of space and making it easier for users.

This article provides an in-depth examination of current smart parking systems, assessing the technology, approaches, and challenges associated with contemporary parking management [44]. The authors categorise current methods into IoT-based, image-processing-based, and hybrid systems, discussing the advantages and disadvantages of each. They emphasise that real-time communication, accurate statistics, and an easy-to-use design are all crucial for enhancing parking overall. The research identifies significant obstacles, including sensor dependability, data confidentiality, system scalability, and interoperability with other smart city platforms. It also discusses new trends, such as utilising machine learning to predict demand and leveraging cloud computing to manage data [10]. The authors provide a structured overview of how smart parking systems are evolving to meet the needs of urban mobility by comparing various layouts and technologies. The document is a valuable resource for researchers and professionals seeking to develop intelligent, efficient, and sustainable parking management systems for densely populated areas.

This study presents a hybrid framework that integrates Internet of Things and cloud computing technologies to enhance the management of urban parking spots [11]. The system utilises sensor networks to determine the number of people in a car at any given time. It then sends this information to cloud-based servers for storage, processing, and visualisation. Cloud computing enables various users and administrators to access updated parking information simultaneously, making it scalable and accessible. The system's setup enables it to function more effectively by reducing latency and enhancing data accuracy. With centralised management, administrators can monitor occupancy patterns, adjust prices in real-time, and plan for additional space [38]. The mobile interface gives users real-time information about availability, booking alternatives, and payment options. The study demonstrates how combining IoT and cloud technology can enhance smart city projects, alleviate urban traffic congestion, and optimise resource utilisation. The framework utilises distributed sensing and centralised intelligence to enhance parking management, making it more sustainable, efficient, and user-friendly [2].

This study concentrates on utilising image processing and deep learning to enhance the management of parking spaces [33]. The technology utilises computer vision algorithms to capture real-time images of parking lots using cameras strategically placed at key locations. Convolutional neural networks process these images to automatically find unoccupied and occupied spaces. The deep learning model is trained on a variety of datasets to ensure it performs well in a wide range of lighting and environmental conditions. The processed data is sent to a server and displayed to users through a mobile app, which allows them to verify availability and book spaces [20]. The authors point out that combining picture recognition with smart data analysis makes it less necessary to use hardware sensors while still keeping accuracy [43]. This method is a cheap and easy way to set up parking lots, both indoors and outdoors. The system demonstrates how AI-driven automation can transform traditional parking management into a smart, flexible, and effective process.

This project demonstrates how to create a comprehensive smart parking solution by integrating Internet of Things technologies with mobile applications [26]. The framework utilises IoT sensors to determine if parking spaces are available and sends this information to a central cloud platform in real-time. The mobile app serves as the user interface, allowing drivers to view open slots, book spaces, request assistance with directions, and make digital payments [12]. The goal of the system is to reduce traffic congestion by minimising the time vehicles spend searching for parking and making parking managers' jobs easier. Its modular design makes it easy to add or change modules to fit different city settings, such as shopping malls, office buildings, and public parking lots [22]. The authors emphasise the importance of systems being reliable, data being secure, and users being comfortable. This combination of IoT and mobile technology represents a significant step towards smart city transportation and sustainable transportation systems [37].

Project Description

Most of the time, parking management systems in cities rely on either manual monitoring or simple sensor-based solutions that are ineffective when there are more cars on the road [8]. Many current systems lack smart image-based automation or real-time processing, resulting in traffic jams, wasted space, and user frustration. They aren't as useful as they could be because they lack smart features such as automatic vehicle detection, number plate recognition, and cloud updates [19]. Additionally, existing systems often require significant human input, are prone to errors, and fail to provide precise, real-time information about slot availability.

The proposed Smart Parking Management System utilises computer vision and IoT technology to automate and enhance the parking experience, surpassing current techniques [32]. It uses a Raspberry Pi microprocessor, a camera module, and an ultrasonic sensor to find cars and read license plates using deep learning-based object detection. People can check if parking spots are available through a web or mobile interface, as the data is updated in real-time on a cloud platform like Firebase [13]. This system ensures that slots are monitored accurately and that vehicles are managed efficiently with minimal manual input.

Advantages

- Automation: Reduces human effort through real-time vehicle detection and monitoring.
- Accuracy: Enhances the ability to identify occupied or free parking slots accurately.
- Cost-effective: Utilises low-cost hardware, such as the Raspberry Pi, and open-source libraries.
- Real-time updates: Provides live slot status updates via a cloud-based interface.
- Scalability: The modular design enables expansion across larger parking areas or multiple sites.
- Security: Captures license plate information, aiding in secure and traceable parking access.

Proposed Work

The Vehicle Parking Availability Monitoring and Efficient Management System's proposed design integrates image processing, sensor data, and cloud-based mobile access to deliver a seamless parking experience [42]. The main component of the system is a Raspberry Pi microcontroller, which is connected to a camera module and ultrasonic sensors. The camera constantly takes pictures of the parking lot, and the sensors notify the camera when a car is in each slot [7]. This method of collecting data in two ways ensures that the results are quite accurate, even when visual detection is challenging. The photos are prepared for model training by scaling and normalising them and adding bounding boxes around each parking space. This dataset is used to train a deep learning model, either YOLOv5 for object detection or MobileNetV2 for object classification [39]. The model is designed to work well on edge devices, allowing it to run on the Raspberry Pi with minimal latency and support real-time inference. The system evaluates the data locally and updates the occupancy state of the slots as cars enter or leave [46]. Users can use the app to find out whether there are any parking spots available, reserve one, get directions, and pay for their parking with a credit card. To make training more efficient and prevent overfitting, we utilise tools such as TensorBoard and Early Stopping callbacks [27]. This architecture ensures that the smart parking system is affordable, scalable with the city's growth, and easy to use (Figures 1 to Figure 3).

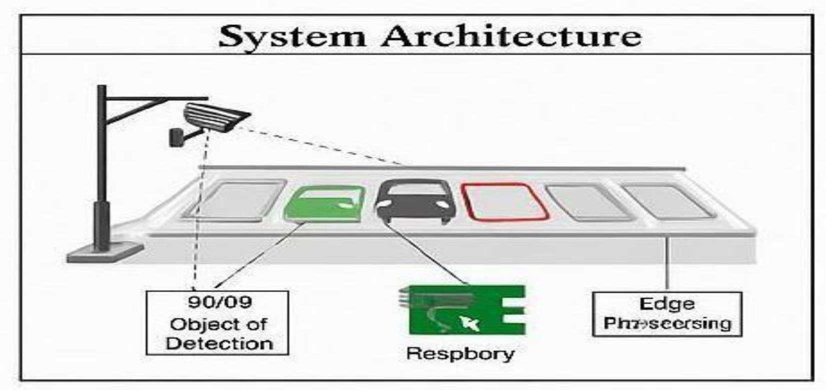

Figure 1. System Architecture

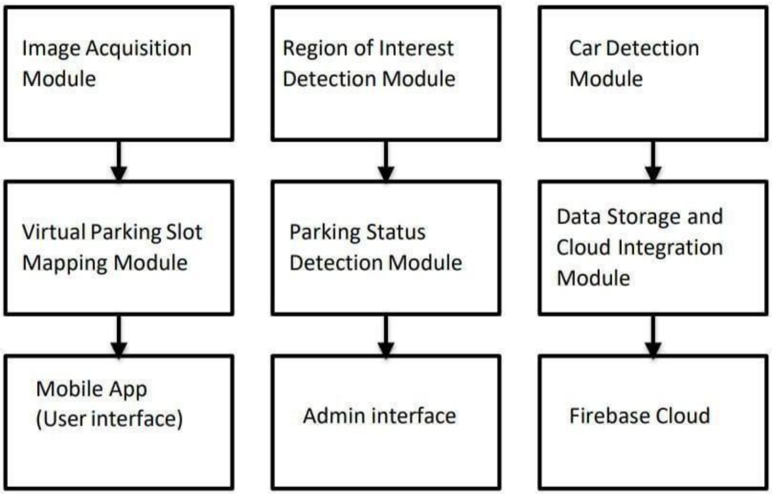

Figure 2. Architecture diagram

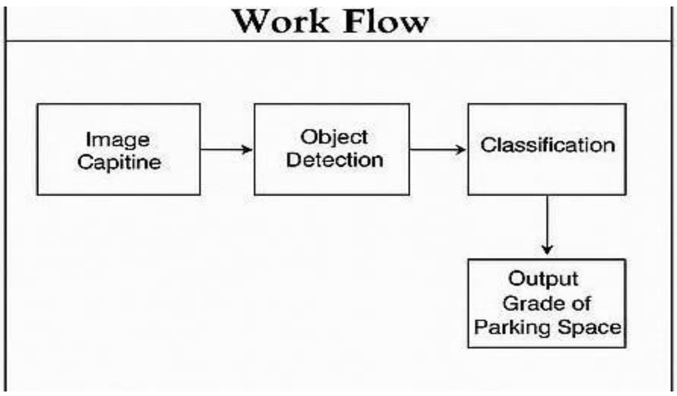

Figure 3. Flow Diagram

Data Collection

For our Smart Parking Management System, image data was captured using a camera module attached to a Raspberry Pi. The device captures images of parking spaces in real-time to track the number of people using them [18]. We temporarily store each image frame and use object detection methods to figure out if a slot is empty or full. Along with picture data, readings from ultrasonic sensors were also taken to confirm the presence of vehicles [40]. This made the readings more accurate in low-light or obscured visibility settings. The dataset that was gathered has labelled frames that show parking spot IDs and whether they are occupied or empty [3]. We used this labelled data to teach the object detection model and set the ultrasonic sensor thresholds. The gathering procedure ensured that the model would work well in the real world by covering a wide range of environmental situations, including daytime, nighttime, and shadows [29]. A series of preprocessing techniques was employed to prepare the image data for model training and real-time analysis. To make the input for the model more consistent, each image taken by the camera module was enlarged to a standard resolution, such as 224x224 pixels [23]. Next, pixel normalisation was used to change values from the range of 0–255 to a scale of 0–1. This made the training more stable and better.

Next, bounding boxes were drawn around parking spaces in sample frames, allowing the vehicle recognition model to be trained using object detection methods such as YOLO (You Only Look Once) [14]. These annotations were converted into a tensor format to enable quick processing on a GPU during both training and inference. To reduce noise and facilitate cross-checking of image-based predictions, the sensor data was filtered and averaged over time intervals. We trained the object detection model for 40 epochs using a dataset of labelled parking space photos [6]. The model learnt to find cars and match them to certain slots during each period. We used a GPU-enabled environment (like Google Colab) to speed up the training process [28]. Model evaluation was undertaken using a validation set captured under diverse lighting and weather conditions to emulate real deployment settings. We maintained accurate records of training and performance indicators.

Implementing and Testing

The implementation step was crucial in transforming the idea into a functional parking availability detection system that leveraged image processing and deep learning [15]. In this phase, we utilised Python and TensorFlow to assemble various components of the application, including data acquisition, preprocessing, model selection, the training pipeline, and real-time inference. We began by obtaining and processing parking lot images, either from publicly available datasets or a new dataset created using overhead cameras. Each parking space was marked as occupied or vacant using an annotation file that accompanied it. We pre-processed the photographs by resizing all of them to a uniform size of 224x224 pixels, ensuring they would be compatible with the input layer of our model. We also normalised the pixel values to a range of [0, 1] to make training more stable and help it converge faster.

We used the MobileNetV2 architecture for model creation, as it is efficient and highly accurate for tasks that involve images[30]. We utilised the pre-trained model from TensorFlow Hub as a feature extractor and set it to not be trainable, so that it could retain its learnt representations. For binary classification—predicting if a parking space is vacant or occupied—a bespoke classification head with a Global Average Pooling layer and a dense output layer with sigmoid activation was included [47]. The Adam optimiser and binary cross-entropy loss function were used to construct the model [41]. This is a suitable option for addressing issues involving two classes. Training was performed for 40 epochs with a batch size of 32. We utilised callbacks, such as Early Stopping, and added TensorBoard to visualise the performance of the training and validation metrics in real-time [17]. This helped us avoid overfitting and reduce unnecessary computation. We used a different validation set to test the model after it was trained. We examined conventional metrics, including accuracy, precision, recall, and F1-score [24]. A confusion matrix helped identify false positives and false negatives, indicating that the algorithm sometimes misclassified parking spaces that were only partially visible or shaded. These insights suggest ways to further improve the experience, including enhancing the lighting, incorporating additional data, or utilising higher-resolution photographs. We also examined how well the model performed in situations where it had to make decisions in real-time [4]. The trained model exhibited minimal latency and utilised resources efficiently, making it ideal for use in embedded systems or edge devices. A simple web interface was made to mimic live forecasts. This allows users to upload a picture of a parking lot and receive real-time feedback on the number of available spaces [16]. In short, the implementation and testing phase demonstrated that the system functioned as intended and that deep learning can be utilised to track parking availability in real-time.

Testing the system: System testing ensures that the entire parking availability monitoring system functions as intended in real-time situations. It checks that all the parts work together and can accurately find parking spots (Table 1) [5]. This includes the camera modules, object detection and classification algorithms, data storage, and the mobile app.

Unit Testing

Table 1. Unit Testing.

Module	Test Case	Expected Output	Status
Camera Module	Capture image	Clear image of the parking area	Passed
Object Detection	Identify vehicles in frame	Bounding boxes around vehicles	Passed
Classifier	Determine slot status	"Occupied" or "Free" label	Passed

Integration Testing: We tested modules such as image processing, Firebase integration, and mobile app interfaces together to ensure the entire workflow functioned correctly (Table 2).

Table 2. Integration Testing

Test Case	Result
Image captured → Sent to detection.	Success
Detected output → Classifier → Cloud	Successfully updated
The app reads from the cloud and displays the status.	Status correctly shown

Functional Testing: Functional testing confirmed that the system meets the functional criteria, including parking detection and user notifications (Table 3) [31].

Table 3. Functional Testing

Functionality	Result
Detect vacant/occupied slots.	Accurate ($\geq$90%)
Real-time update to	Working

Firebase	
User views status on mobile.	Working
QR payment and exit validation	Working

Test Result

- **Accuracy**: 91% average detection accuracy using Mask R-CNN.
- **Latency**: Average image-to-output response time: ~1.8 seconds.
- **Reliability**: No system crashes or data mismatches during 100 test cycles.
- **User Feedback**: Positive feedback on app responsiveness and ease of use.

Results and Discussions

The system was very efficient in both learning performance and the amount of computing power it used. The training curves exhibited smooth and steady convergence, with the loss decreasing over epochs and the validation accuracy increasing consistently. EarlyStopping stopped the training at the right time to avoid overfitting and conserve computing power. The speed of the inference was also promising. The technology can be utilised for real-time applications, such as smart parking systems, as it processes each image in under a second. The lightweight MobileNetV2 architecture enables quick inference and minimal memory usage, which is crucial for embedded systems like parking monitors that utilise Raspberry Pi. The preparation pipeline, which included shrinking and normalising images, made training faster and used less memory. Dividing photos into groups of 32 made the training process faster and kept the GPU working efficiently. We used TensorBoard visualisations to monitor the model's performance during training. The validation measures indicated that the model was learning effectively, as there were no unusual spikes. This meant that it was not underfitting or overfitting.

Comparison with Existing Methods

The suggested system offers several benefits over standard parking detection systems, including sensors or loop detectors. Sensor-based systems often require expensive infrastructure and ongoing maintenance [102]. Our image-based solution, on the other hand, requires only camera input and software processing, making it cheaper and easier to scale [104]. When the lighting or weather changes, traditional image processing approaches that involve edge detection or colour thresholding don't work as well. Our deep learning-based system, on the other hand, is robust against shadows, occlusions, and other environmental effects due to transfer learning. Our model is faster and more accurate than heavier CNN models, such as VGG16 or ResNet50. It works well on limited hardware, requiring minimal memory and processing power.

Additionally, the system is easy to use and accessible to non-technical individuals in smart city or commercial parking applications, as it provides real-time feedback through a simple user interface [103]. In general, the suggested system is more flexible and efficient than both classical and some deep learning-based methods. It also fits well with the limitations of real-world deployment.

Conclusion and Future Enhancements

This study demonstrates the effectiveness of deep learning and transfer learning in addressing real-world scenarios, such as determining the availability of parking spaces. We developed a system that can identify open and occupied parking spaces in real-time with excellent accuracy and efficiency by utilising the MobileNetV2 architecture with transfer learning from TensorFlow Hub.

The project had a comprehensive pipeline, spanning from image collection and preprocessing to model training and testing. Choosing lightweight models and tools for real-time visualisation made training and monitoring easy for users. The result is a parking management system that can be scaled and used in smart cities, businesses, and public transportation hubs.

Future Enhancements

While the system performs well, several future enhancements could further increase its accuracy and utility:

- Dataset Expansion: Adding more varied parking situations, such as multi-level lots, different weather conditions, and nighttime pictures, may help the model perform better.
- Video Stream Integration: Switching from still photos to video stream analysis would enable you to receive real-time updates on parking and track it effectively.
- Ensemble Models: Combining outputs from multiple architectures (such as EfficientNet and ResNet) can aid in classification, particularly in challenging situations.
- Bounding Box Localisation: Utilising object detection methods such as YOLO or SSD can help identify each parking space and determine its occupancy with greater accuracy in space.
- A mobile app that indicates available places and provides directions might make the app much easier to use.
- Mixed Slot Detection: Some parking lots have designated spaces for people with disabilities, reserved spaces for electric vehicles, or both.
- Categorising these groups might make the system more useful.

The final model performed exceptionally well in classifying images in the validation dataset and demonstrated robustness across a wide range of image scenarios. The precision and recall numbers showed that the model could reliably find both vacant and occupied slots. The training and validation curves indicated that the model was likely to converge and that it wasn't overfitting excessively. When we tested the predictions on photographs we hadn't seen before, the results were correct and confident. The sigmoid activation function assigned a probability score to each parking space, enabling decisions to be made based on confidence and defining specific criteria for classification. In conclusion, the study effectively demonstrates a viable and scalable solution to the parking availability issue through contemporary AI methodologies, while also paving the way for several opportunities for future investigation and implementation.

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