Off-Street Car Detection Algorithm for Smart Parking

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Abstract:

In the contemporary landscape of burgeoning smart city initiatives, the dire need for efficient management of urban spaces, particularly in resolving vehicular congestion and parking mismanagement, is a paramount concern. Despite the rapid technological advancement, the swelling number of vehicles often leads to inefficiencies, wasting time and exacerbating environmental pollution due to congested on-street and off-street parking. This has underscored the imperative for a sophisticated smart parking system to guide individuals to vacant parking slots swiftly. While ongoing research predominantly relies on sensor-based approaches, a novel solution emerges through this paper's proposal of a Camera-based Smart Parking System. This prototype detects vacant parking spaces in real-time and seamlessly notifies users through an intuitive Android application, potentially revolutionizing parking management in smart cities.

However, as smart city development progresses, further advancements in hardware compatibility and economic feasibility become essential. The traditional sensor-based approaches, gradually tapering on the product life cycle curve, are being overtaken by the promising camera-based systems, which adeptly mitigate the drawbacks of their predecessors. Despite the merits, the camera-based approach introduces its challenges. The proliferation of hardware and the extensive camera deployment requirement significantly inflate costs. To counter these limitations, this paper proposes a prototype of a CCTV camera-based smart parking system, leveraging pre-installed infrastructure to detect available parking spaces and relay this information through a user-friendly mobile application, aiming to strike a balance between efficiency and cost-effectiveness in modern parking solutions for burgeoning intelligent cities.

Introduction:

In the current urban landscape, parking space is increasingly seen as a coveted privilege rather than merely owning a vehicle. The escalating number of cars flooding the roads has resulted in severe traffic congestion and exacerbated parking predicaments. Studies suggest that nearly 20 percent of traffic congestion in major cities can be attributed to drivers scouring for parking spots. In response, municipal corporations have initiated various measures to alleviate these challenges, primarily by creating more parking spaces. However, a significant issue persists as many of these spaces still need to be utilized due to a lack of awareness and negligence, posing concerns not just for governmental bodies but also for large institutions, malls, and private parking providers. To address this quandary, a

'Smart Parking Solution' emerges, leveraging advanced technologies for efficiently operating and managing parking spaces within an area. Although widely adopted in some countries, especially in Europe, its widespread acceptance still needs to be improved by its inherent complexity.

This project endeavors to develop a fully automated system to assist users in the real-time detection of available parking slots. Integrating a camera module with a Raspberry Pi board, the system continuously captures live feeds of designated parking spaces. Deep learning algorithms embedded within the Raspberry Pi process these feeds, providing live updates on the availability of empty parking slots. This real-time information is then relayed to an Android application installed on users' mobile phones, enabling them to locate vacant parking spots effortlessly. As smart city development progresses, there is a pressing need for further advancements in hardware compatibility and economic viability. While the sensor-based approach diminishes the product life cycle curve, the recently proposed camera-based approach has exhibited promising potential in overcoming the limitations of its predecessor. However, this method also confronts challenges due to the substantial hardware requirements and the need for widespread camera installation, leading to high incurred costs.

In response to these challenges, a prototype of a CCTV camera-based smart parking system is proposed, leveraging pre-recorded video feeds to detect empty parking spaces and disseminate this information through a user-friendly mobile application. This innovation seeks to streamline the parking experience while addressing the economic constraints associated with hardware-intensive solutions. By optimizing existing infrastructure and employing innovative technology, this system aims to balance efficient parking management and cost-effectiveness in the burgeoning landscape of smart city initiatives.

Literature Review

The main objective of Smart Parking is to automatically detect a free parking space and allow a commuter to park their vehicle in that space. The term Smart Parking was introduced many years ago and has been practiced for a long time. The recent developments in artificial intelligence (AI) have brought many changes to the system, eventually increasing the efficiency of the product and reducing hardware dependency. Earlier, when the term Smart Parking was introduced, Artificial Intelligence and Machine learning algorithms were not developed or used. So, in that situation, an intelligent parking system 1.0 was created using various technologies like radio frequency identification (RFID), wireless sensor network (WSN), Bluetooth, Wi-Fi, etc.

Smart Parking 1.0

An intelligent parking system 1.0 was developed using sensors. The sensors played a significant role in the system by detecting the presence of a car in a parking space. Based on the above statement, sensors must be fitted/placed on the ground or at a height to detect the presence of a camera. This led the authorities to shell out or dedicate a vast amount of money to install and maintain the system, forcing them to use it. Also, as a part of the intelligent parking system 1.0, an RFID-based innovative parking application was developed, which implements an automated check-in and check-out of the car by scanning the RFIDs as presented in [1].

Smart Parking 2.0

Smart parking 1.0 was further improved, and various new models and modifications came up; an intelligent parking guidance and information system that uses a webcam to detect free parking slots and provides SMS-based reservation service to the driver is proposed in [2], image processing technique is applied to design some intelligent parking guidance system [3]. A low-cost smart parking system was developed in [4] based on the Internet of Things (IoT) for managing spaces. Smart Parking Management System for Smart Cities [5] is an enhanced version of the systems mentioned above that detects an empty parking slot using a sensor and provides a facility to have a look at the parking infrastructure on the user's mobile application, thus saving driver's search time for an empty parking slot. Vision-Based Parking-Slot Detection: A Benchmark and A Learning-Based Approach [6] uses video frames and detects an open parking space by observing the boundary lines drawn within a slot. [7] proposes a location-centric IoT cloud-based on-street parking violation management system for faulty vehicle parking.

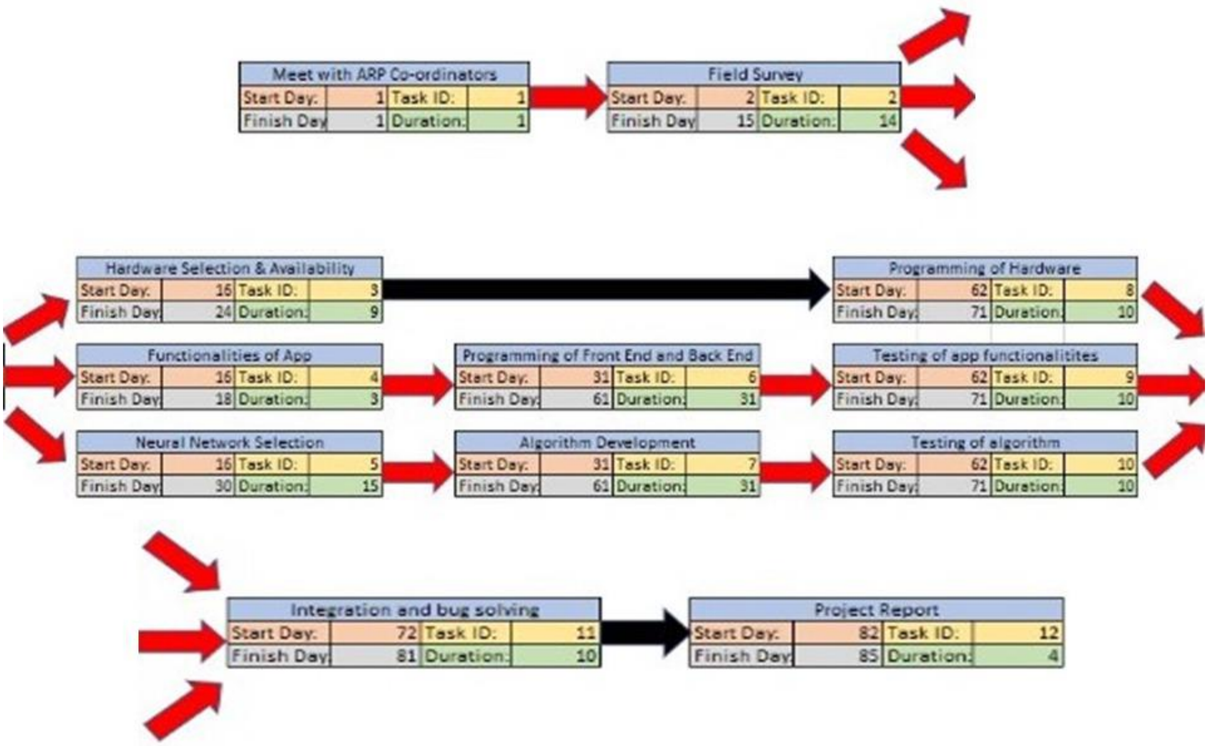
Project Objectives

1. To create a system that gives users real-time data of available parking spaces for places with parking problems.
2. To create an extremely user-friendly mobile application that becomes a bridge between the user and the system.
3. To develop a system that will solve parking problems on-street and off-street.
4. To create an efficient and universal algorithm for detecting empty parking slots from pre-recorded video feeds.

Technical Plan

The below figure shows the overall project plan which we intend to follow. We have designated a few days for every task. As per the plan, we want to complete the project in 85 days, which we have allocated.

- 1 day - For the ARP meeting with our mentors.
- 14 days - For the field Survey.
- 9 days - For Hardware selection. Simultaneously, 3 days are allocated to decide the functionalities of the app. Also, 15 days are allocated for neural network selection.
- 43 days - For the front-end and back-end development of the app, followed by 31 days for neural networks algorithm development.
- 10 days - Programming the hardware and testing the app functionalities and algorithms.
- 10 days - To integrate software, hardware, algorithms, and debugging problems.
- 4 days - For all the documentation.



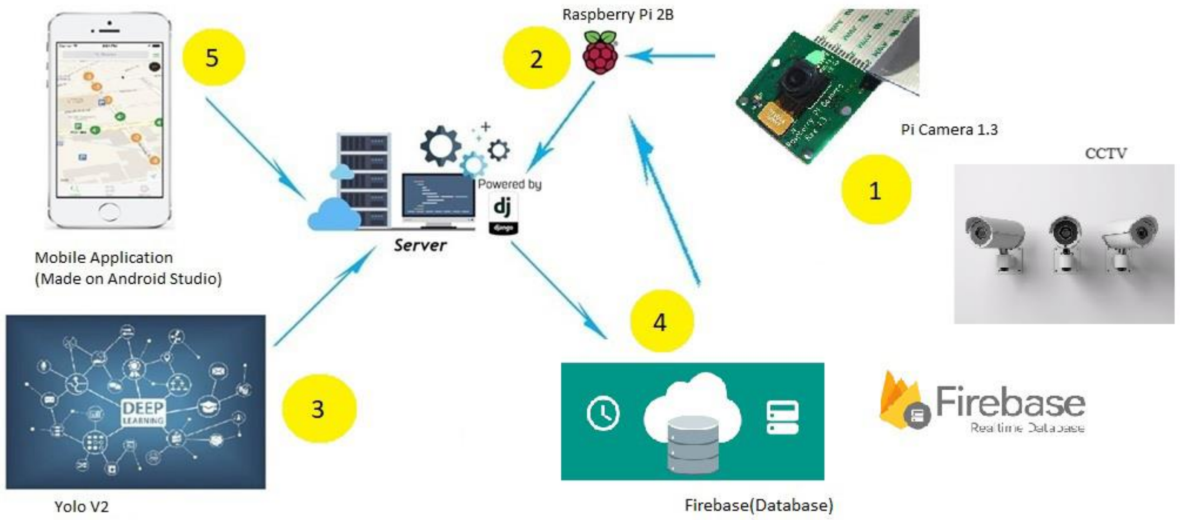
Theoretical Approach of the Project

The project addresses the pressing parking issues in metropolitan areas, aiming to rectify both on-street and off-street parking problems. By seeking an equilibrium between parking supply and demand, it endeavors to mitigate congestion and curb pollution. The central focus lies in efficiently identifying vacant parking spaces and relaying this real-time data through an Android application. On the technical front, the project comprises a blend of hardware and software elements. The hardware setup involves employing a camera module interfaced with a Raspberry Pi board or pre-installed CCTV cameras positioned strategically at optimal heights to capture clear frames of parking slots. These cameras continuously stream live feeds processed by complex deep learning algorithms trained extensively with thousands of car images in various parking scenarios, ensuring comprehensive efficiency. However, the complexity of the algorithms might induce latency issues, which can be mitigated through upgrades to more robust hardware specifications.

Through their live feeds, the hardware systems allow the algorithms to discern empty parking spaces, updating a database every few seconds with the current status of available slots. Simultaneously, an intuitive Android application simplifies user interaction. Upon opening the app, users are prompted to enter their mobile number for verification, subsequently receiving an OTP to confirm their legitimacy. New users proceed to a registration page, furnishing necessary information, while existing users can opt for Gmail-based logins. The application provides a seamless interface for users to access real-time parking status. The backend operations, integrated via the Firebase database, manage user data, verification processes, and OTP delivery, display live parking slot status on the application interface, and regularly update users with the latest parking availability information.

Both iterations of the project, whether utilizing a Raspberry Pi-based camera system or pre-existing CCTV cameras, prioritize accuracy in identifying empty parking spaces. The amalgamation of cutting-edge hardware and user-friendly software solutions marks a significant step towards alleviating parking woes in urban environments, aiming to streamline parking management while reducing congestion and environmental impact in metropolitan areas.

System Design



The prototype's comprehensive functionality revolves around using either a Raspberry Pi-powered camera or a CCTV camera interfaced with deep learning algorithms. In the case of the Raspberry Pi setup, a camera is positioned optimally to capture a designated area, with its feed processed into smaller frames by the onboard processor. Integrated deep learning algorithms within the processor facilitate the determination of parking status, which is subsequently stored in a database. This database holds crucial user information like phone numbers, names, and email IDs. When users seek parking availability, they log into the application and query the database, prompting the display of real-time parking status on their screens.

Conversely, the CCTV-based system involves a camera recording frame of the parking slots, similarly positioned at an appropriate height and angle for adequate coverage. The video feed from the camera is directed to a deep-learning algorithm that assesses the parking slot's status. This status is continually updated within the database. Users access the application, log in, and inquire about parking space availability, triggering the database to provide the group promptly. Both systems aim to empower users with real-time parking information, facilitating efficient utilization of available parking spaces through a user-friendly interface and a robust database infrastructure.

Components

Hardware

1. Raspberry Pi 2B
2. Pi Camera v1.3

Languages

1. Java
2. Python
3. Yolo V2
4. Firebase

Software

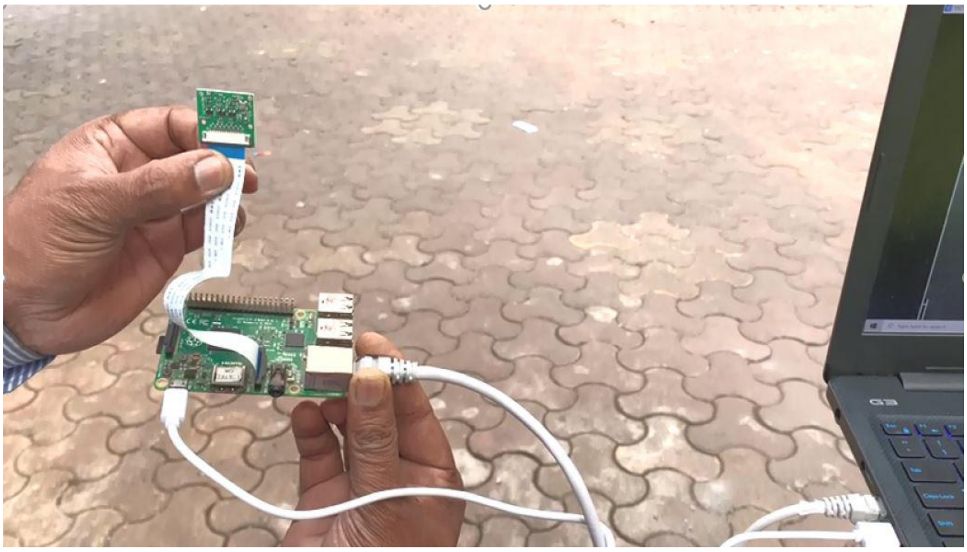
1. VNC Viewer for Raspberry Pi
2. Visual Studio
3. Android Studio

Simulation & Experimental Results

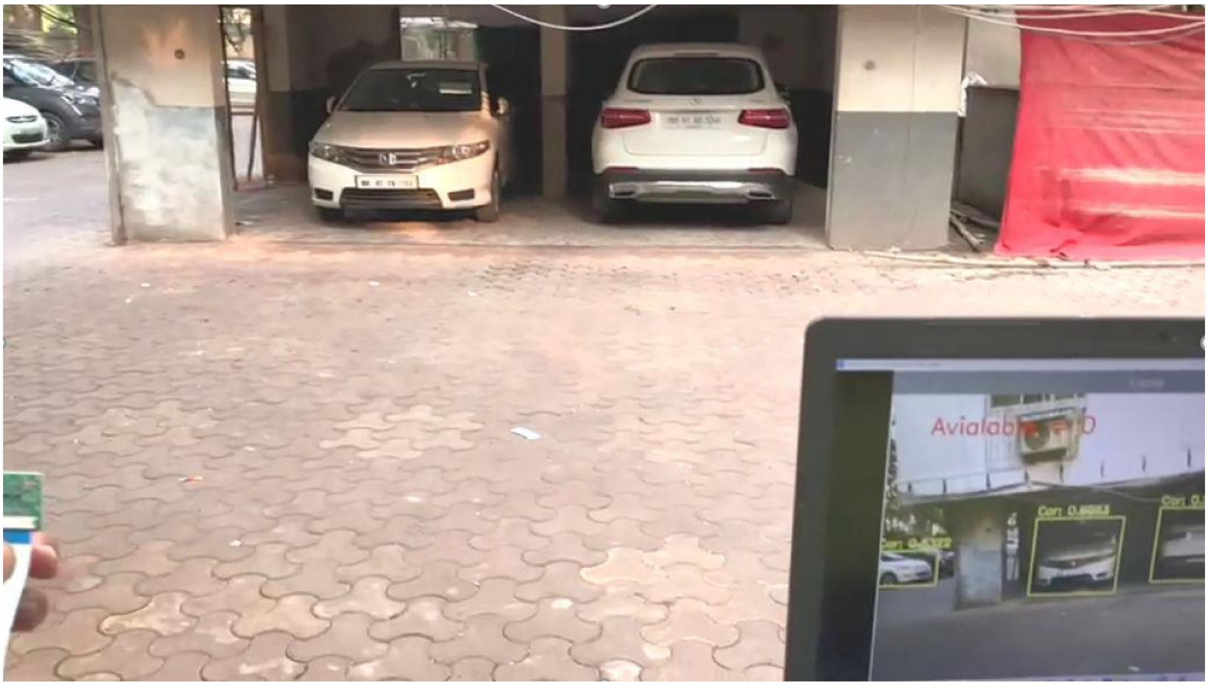
Part-1

The output of the visioned system is completed after a series of various steps depicted below.

1. In the below image, the camera is interfaced with Raspberry Pi and is held in front of the parking slot, the status of which is to be detected.

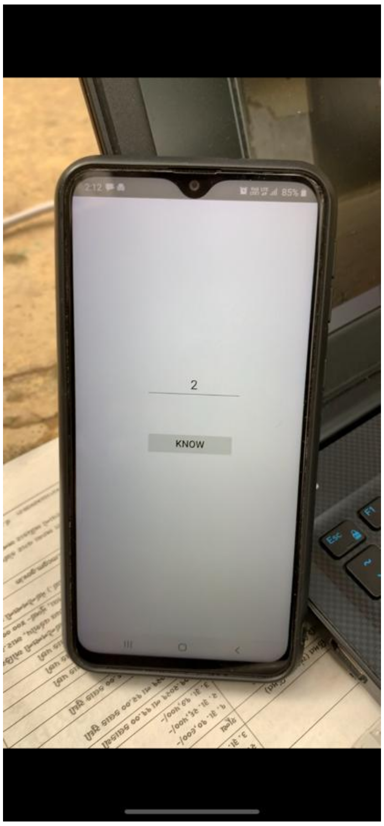


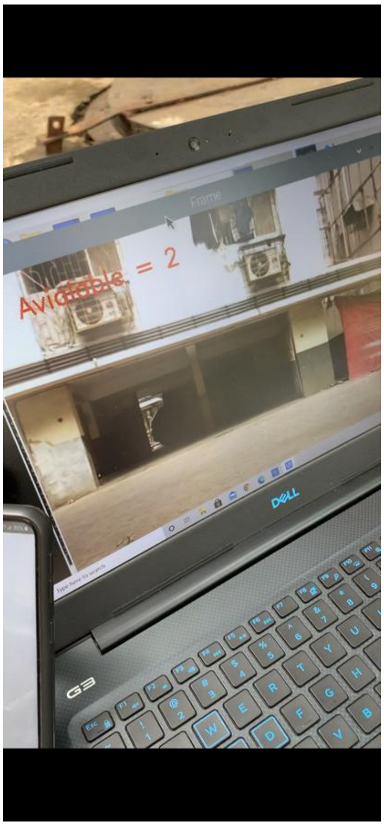
2. This is the stilt parking slot, which contains two cars and is the target frame of the algorithm.



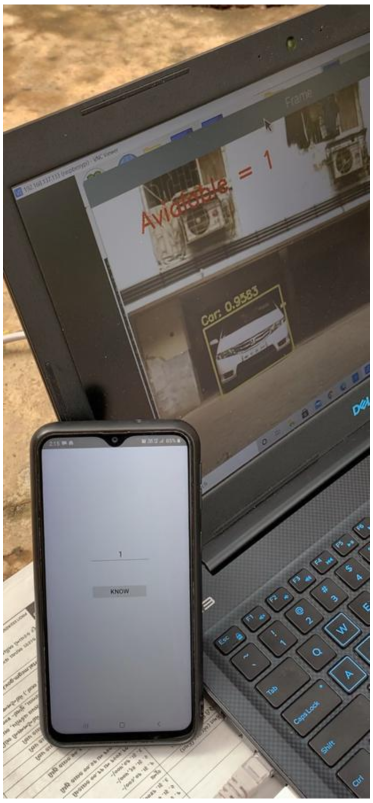
3. Then, the live video feed is given to the pre-trained model, and the output generated by the model, when merged with the video frame using OpenCV, looks like this. Since both cars are present, the available slots are equal to 0.

4. Then, both the cars are taken out of the garage, and the available slots equal to 2 and it gets updated in the Android application as well.





5. One car is parked again in the garage, which gets detected immediately by the algorithm; thus, available slots equal 1, and the Android application gets updated.

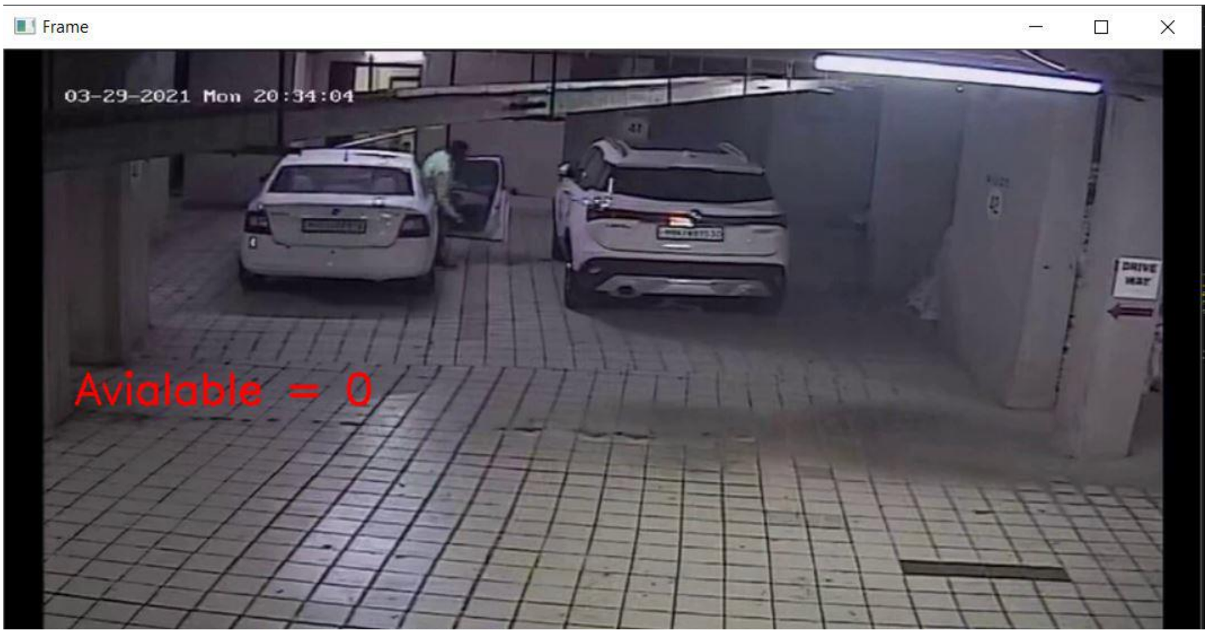


Part-2

1. Here is the parking slot with parking space for two cars. The image shows the empty parking slot compared to the system's 2 available parking spaces output.

2. The parking slot is now getting filled where one car has just entered the slot ready to be parked, and the algorithm has successfully detected that the car has filled the slot.

3. Now, the slot has two cars parked, and the algorithm has updated the number of slots available to zero.



Conclusion

This comprehensive report delineates the construction of two distinct prototypes: a Camera-based Smart Parking System and a CCTV Camera-based Smart Parking System, offering innovative solutions for managing on-street and off-street parking. These systems aim to provide drivers with real-time information regarding available parking spaces. The Camera-based prototype operates by capturing a live video feed from a camera, processing it through a deep learning model, and subsequently notifying users via the application about the presence of empty parking slots. Conversely, the CCTV Camera-based prototype acquires video feed from CCTV cameras, employs deep learning models for processing, and alerts users about the live status of parking slots through the application. Results from both prototypes validate their functionality in delivering real-time information about parking space availability, thereby meeting the primary objective of this study: offering efficient and accessible parking management solutions for urban areas.

Future Work

The future trajectory of this project holds immense potential for enhancements across various facets. Extensive training with an expanded repository of images and diverse model parameter variations could be undertaken to bolster the model's accuracy. Furthermore, the Android application interface stands open for modification, potentially integrating Google Maps to assist users with navigation to available parking spaces. The issue of hardware compatibility could be resolved by employing a network of CCTV cameras connected to a centralized server computer, broadening the scope for scalability and efficiency. Additionally, the system's capabilities could extend beyond mere information provision, seamlessly integrating with reservation and payment systems for parking slots and catering to the needs of malls and various organizations. While the current demonstration involves a single camera slot, the system's adaptability allows for displaying and utilizing multiple camera feeds. Although the results showcased stem from CCTV footage within an underground parking system, the system's applicability extends to surface parking areas, promising broader integration and utility in diverse parking scenarios.

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