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Deep learning based smart parking model using Mask RCNN

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ABSTRACT: In this rapidly growing economy and modernizing population, the number of vehicle users increases exponentially demanding more parking space. The rising number of vehicles on the road, combined with poor parking space management, results in various traffic related concerns like traffic jams, casualties, time wastage, atmospheric pollution and contributes to needless fuel consumption. These issues have enforced the need for a Smart Parking System that will help optimize parking space usage, improve the efficiency of the parking operations and help level the traffic flow. To solve this issue we have created a new machine learning model based on the fastest deep learning neural network model MaskRCNN, our model has the highest accuracy based on our testing and training on pklot dataset. The proposed model counts the number of occupied and unoccupied parking slots. It detects cars with cameras instead of embedded sensors which reduces the overall cost of the system significantly. It can be used for detecting empty parking slots for any parking area. Further, with the proposed model, latency is reduced. The project is implemented using Python language and Jupyter Notebook.

KEYWORDS:WSN, IoT, Cloud computing, Smart car parking, Mask RCNN, Image Processing, Deep Learning.

I. INTRODUCTION

The increase in population has also led to an increase in human mobility. This increased the number of vehicles which in turn affected the parking situation. Nowadays, people buy cars even if they have nowhere to put them, and even some streets are becoming a parking spot which then causes congested traffic movements.

Metropolis worldwide entices people to live, work, and visit as they provide finer job opportunities, public resources, and services. As the city urbanizes, the number of vehicles elevates accordingly. Instead of utilizing public transportation, people travel in personal vehicles for convenience and comfort. The demand for parking spaces is usually much greater than the supply due to the lack of a well-planned policy for parking facilities. Additionally, downtown areas are generally saturated with commercial office buildings but not as many parking spaces. Therefore, drivers end up spending a significant amount of time circling their destination, searching and waiting for available parking areas. Accordingly, if drivers can have real-time parking availability information, they will adjust their travelling schedule without spending time cruising the city in vain.

Manville and Shoup [1] surveyed the percentage of total parking spaces of different cities. Averagely, parking coverage takes 31 per cent of land use in big cities, like San Francisco, 81 per cent in Los Angeles and 76 per cent in Melbourne, while at the lower end we find New York with 18 per cent, London with 16 per cent, and Tokyo with barely 7 per cent. Cities with more on-street parking space need to embrace smart parking to avoid drivers cruising for free parking areas. A survey [2] shows that during peak hours in big cities, the traffic generated by vehicles looking for parking lot vacancy takes up 40 per cent of total traffic. Finding available spaces during weekends or public holidays can take more than 10 minutes for about 66 per cent of the visitors

In terms of the effect on pollution, the paper [3] claims that according to an estimate locating an available car parking slot in Los Angeles costs about 95,000 hours, 730 tonnes of CO_2 and 47,000 gallons of fuel. Therefore, to address the issues mentioned above, smart car parking systems have become an essential need. For this reason, a simple but efficient system is required to monitor the parking spaces to facilitate the drivers in finding availableparking space. When a new vehicle enters the parking area, the proposed smart car parking system uses image processing and fog computing to provide information about the availability of parking slots. The reasoning behind using fog computing in the proposed solution is that the details about the vacant parking spaces must be modified on a regular basis; thus, reducing the latency along with the network bandwidth consumption.

The paper is structured as follows: Section II covers the literature survey of the existing smart parking systems. Section III focuses on the concept of Mask RCNN. Section IV covers the proposed system, it's architecture and methodology. Finally, section V and VI covers results, future scope and conclusion obtained from the implementation.

II. LITERATURE SURVEY

This section discusses the research works that are related to smart car parking systems. Typically, the drivers find the parking space by driving around the parking areas, roadsides, or streets. However, with the advent of technology and smart devices, such as smartphones and surveillance cameras, several automated methods to help drivers park their cars have alsobeen proposed. An IoT based smart car parking system is presented in [4] where data is collected with the help of different distributed sensors, analysed and processed locally by using various machine learning algorithms. A phone application is used to find the nearest parking location using Google API, providing a real-time reading of the traffic status. Further, cloud services are used to process and save data collected from a micro fog controller. The user gets an immediate response as soon as the data is processed on the cloud.

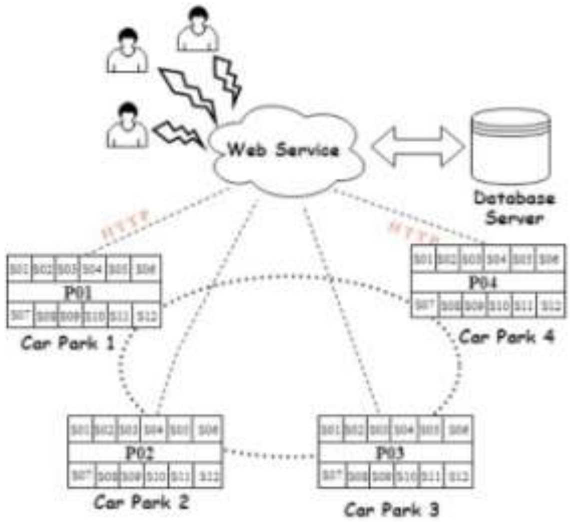

Fig. 1.System Architecture [6]

In [5], the components used were Infrared sensors, Raspberry Pi, cloud server, and mobile application to implement a smart parking system. Twelve sensors are connected to the Raspberry Pi, which is registered through web API. They had used sensor numbers to detect a vacant parking slot. With the admin portal and other components, data is processed, and information about the vacant slots is passed onto the user to its mobile phone.

The [6] proposed system uses the IoT technology to monitor car detection at parking places consisting of Ultrasonic Sensors and Arduino. The user hasto log in to the system, select an appropriate parking location according to its current location. If he/she continues to book the slot, the slot is marked as ”Partially reserved” until the user completes the whole booking process, and lastly, the slot will be marked as ”reserved” as soon as the user reaches the slot. In the case of vacant slots, the slots are marked as “available”.The limitations of the systems mentioned above are smartphone is mandatory, infrared or ultrasonic sensors cover a very short range and increases the overall cost of the system, cloud servers impose high latency rate and increased computational power. Furthermore, the efficiency of the sensors depends upon the position and pose of the vehicle. While using sensors, it becomes extremely important that the vehicle is parked properly for the sensor to get enough details about the obstacle. So, the efficiency of the sensors highly depends upon the pose and position of the vehicle. However, when we use image processing techniques, the efficiency and accuracyincrease in such environments.

A [7] Deep Convolutional Neural Network (DCNN), a computer vision-based technique, is used to detect vacant slots in three major steps: markingpoint detection, local image pattern classification, and parkingslot inference are included for the same. This technique doesn't present any associated framework to help drivers find the closest parking slot.

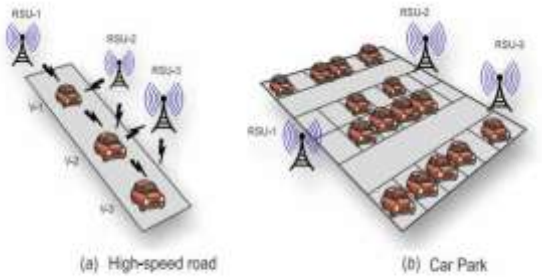

Fig. 2.High speed (highway) versus low-speed traffic conditions [8]

In [8], the model allows users to enter into a crowded parking lot to find a good parking slot instantly. A smart combination of Distance Geometry based Parking(DGP) and Vehicle-to-infrastructure is used to provide reliable localization in hybrid indoor and outdoor environments. Its most important drawback is the complexity of DGP algorithms for vehicle localization, due to which one has to buy an external facility for calculation purposes.

In [9] authors have proposed a model consisting of three layers, the application layer, communication layer, and sensor layer. The cloud provides data storage and computing resources, stores the 'big data' of available car parking lots, car's location, user's location, car parking area, profiles, etc. Web Servers acts as a bridge between the mobile apps tier and the cloud tier and modularises web applications into bundles. Nevertheless, Hadoop's database is used to support real-time queries. An automatic request is sent by the application when a user approaches the University campus to a parking webserver asking for available car parking lots. The server finds the 'best' available car parking lot for this user, and the driving directions are then returned to the user along with a detailed map.

In [10] a smart and secure parking reservation system using Global System for Mobile Communications (GSM) technology has been proposed. This system is divided into two modules parking lot monitoring and security reservation module. For the monitoring module, the layout animation is used to display the parking lot status. In the reservation module, SMS service is required by theusers for reservation of the parking space and only through the password received one can enter or exit the parking lot. The drawback of the proposed scheme is that the users need to reserve the parking lot first, which can create a lot of trouble if they do not have a cell phone. When many incoming information is occurring in a short time, the GSM system creates bottlenecks. If the database is of the system, it can't send the confirmation to the user.

This [11] paper presented an invention that could be applied to monitor and manage vehicles in a parking garage by informing drivers about the number of available parking spaces and in which area should they be directed. The scheme is based on modifying the Wireless Sensor Network and the use of RFID and ZigBee technology. To evaluate other meaningful metrics such as time, the information obtained from each sensing node is processed collaboratively. However, the use of RFID increases the cost of the system, and node-to-node implementation requires more time. The system allows one by one parking only, is time-consuming, and prevents multiple check-ins or check-outs at a time.

In [12] an agent-based coordination network between drivers and car parks is proposed.

The prototype is designed using the Multi-Agent Systems Engineering methodology. The system considers three criteria for driver demand: negotiation of parking fees, the distance from the current location to the chosen car park and finally, park's booking and reservation. The negotiation algorithms are employed to bargain on parking prices and calculate the driver's shortest path. The limitation of the proposed scheme is that the system is available only in In-Vehicle Advanced Information Systems, which are the standard equipment in the expensive and luxurious cars only, and the cost of deployment is also very high.

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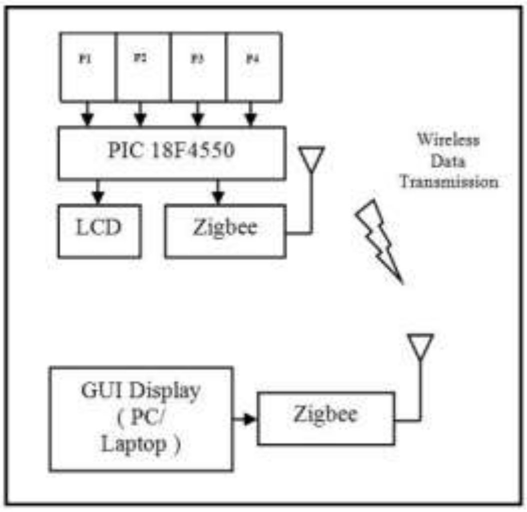

Fig. 3.Hardware architecture of the system [13]

The [13] author proposes a prototype of the Monitoring Parking Space Vacancy System in this paper. The system consists of a parking lot vacancy monitoring module and a master module. Tracking parking vacancy module's LCD displays the status of parking lot vacancies, and the master module searches for empty parking spaces. The digital infrared sensors provided in the parking lot are used to sense the parking lot continuously. Then, the micro-controller sends the information obtained from the digital infrared sensor to both the LCD and Zigbee module. The master module consists of the continuously updated status of the parking lot. The LCD screen placed at the entrance of the parking lot displays the number of available parking spaces. The drawbacks of thesystem are that the cost of implementation is very high and the infrared sensors used are very sensitive to the sun and any environmental object, so the sensing accuracy is not so good.

III. BACKGROUND

Image detection in camera-based smart parking systems is quite difficult. [19] [22] Visual input can greatly differ based on time of day and the weather. This has been a hurdle stopping camera-based smart parking systems from being used. To overcome such problems deep learning is particularly suited for parking slot detection. Thus, we will be using Mask Region based Convolution Neural Network (Mask RCNN) in our approach.

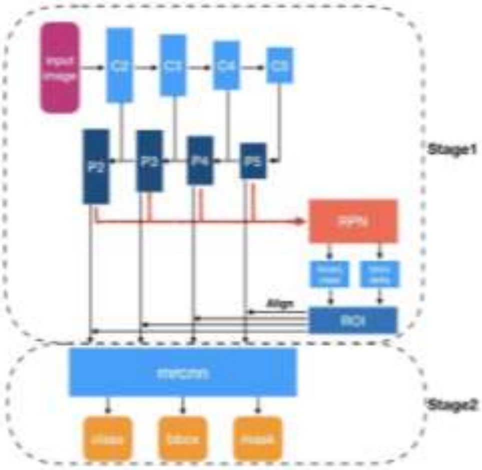

Fig. 4.Mask R-CNN structure

Mask RCNN [20] is a deep neural network aimed to solve instance segmentation tasks. It is used to separate different objects in an image or a video. Instance segmentation assigns a label to each pixel

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of the image. It is used for tasks such as counting the number of objects. There are two stages of Mask RCNN:

1. It generates [21] proposals about the regions where there might be an object based on the input image.
2. It predicts the class of the object, refines the bounding box and generates a mask in pixel level of the object based on the first stage proposal. Both stages are connected to the backbone structure.

IV. PROPOSED SYSTEM

Figure 5 depicts the planned architecture. The proposed system will be able to do the following tasks:

1) Car Detection: It is very important to first do parking car detection before parking slot recognition. Car detection algorithms can be built using OpenCV but the main issue is to build a proper dataset. If we can create a bigger dataset to train a Mask RCNN based model then we can use our own model over built-in algorithms in OpenCV or Dlib. Attributes to consider: Accuracy, Speed, Computation Power, Use case (Actual working).
2) Slot Recognition: After performing car detection task we can use slot recognition models to identify the parking slot status. These models are trained on 11,000 images. Based on our requirement we use Mask RCNN model to create such big datasets. Also, it has high accuracy. The reason to use Mask RCNN is because it does pixel-to-pixel alignment between network inputs and outputs.
3) Counting Number of Cars: Once the system is done with the car detection we can use this data for counting number of cars in the area. Each parking area is covered by cameras hence this count prediction can be done based on the camera footage itself. By counting number of cars detected by the each camera we can detect number of occupied slots in the parking area. The proposed solution is completely based on the car detection algorithm but in reality, we might not be able detect cars each time. To back up this solution we can use object detection models like YOLO.

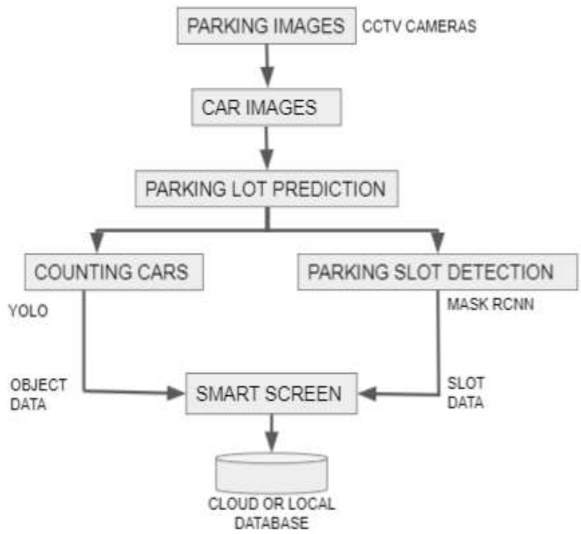

Fig. 5. Flow chart of the proposed system

V. METHODOLOGY

Algorithm I:Filtration and Load Balancing Algorithm
Input: Live image feed process data set
Output: filtered image in fixed size block and send eachblock to processing Mechanism

Steps:
1. Filter related image i.e., Processed image. Allother unnecessary image will be discarded.
2. Divide the image into Appropriate frame using extraction method.
3. Transmit Unprocessed image directly to aggregation step without processing.
4. Assign and transmit each distinct image block of Processed image to various processing steps in Data Processing Unit.

Description: This algorithm takes live data and then filtersand divides them into segments and performs load-balancingalgorithm.In step 1, related data is

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filtered out.In step 2, filtered data are the association of different keyvalue pairs and each pair is different numbers of sample, whichresults in forming a data block.
In further steps, these blocks are forwarded to be processedby Data Processing Unit.

Algorithm II:Processing and Calculation Algorithm
Input: Filtered image
Output: Normalized frame image.

Steps:
1. For each frame repeat the segmentation process
2. Normalize the extraction data for all the frames
3. persist the image into data store and forward it.

Description: The processing algorithm calculates results fordifferent parameters against each incoming filtered image andsends them to the next level.

Algorithm III: Multi object Summarization Algorithm usingMask RCNN

Input: Frame extraction Data.
Output: Final result summary

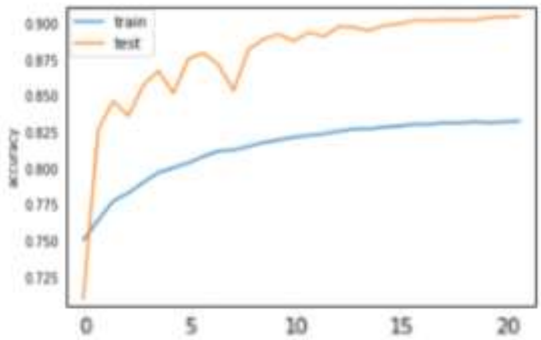

Fig. 6. Accuracy v/s Epoch Cycles Plot

Steps:
1. Gather the data from data store in normalized format.
2. Apply Summarization for individual image from the totalframes capture.
3. Persist the final detected summary into data store.
Description: here the data is collected and the resultsfrom each modal is processed against all and then combines,organizes, and stores these results in database.

VI. RESULT

The project is to detect whether the parking spot is available or occupied. For this project we used the pklot dataset that has enough data for training a deep learning model and there are also xml files containing all the annotations whether the spot has been occupied or not. The model used is the Mask R-CNN which performs well on object detection and segmentation.

This model was pre-trained on the COCO dataset. The approach was to train the top layer of the model from the pre-trained weights on the PKlot dataset (https://web.inf.ufpr.br/vri/databases/parking-lot-database/).
For the data preparation:We created a train and test folder with images and labels.

- train (11,000 images)

– images (.jpg files)
– labels (.xml files)

- test (1,417 images)

– images (.jpg files)
– labels (.xml files)
By parsing the xml files using XML.etree.ElementTree. We can extract contours of bounding boxes.

The config class that we want the model to be trained on is:

- NUM CLASSES = 1+2 (background+occupied+empty)
- STEPS PER EPOCH = 50

Once the model saved. We need to load the maskRCNN model in 'inference' mode and load our saved model. We use the mask-RCNN class to draw the bounding boxes. The config class that we want the model to be tested on is:

- IMAGES PER GPU = 1
- GPU COUNT = 1
- NUM CLASSES = 1 + 2
- DETECTION MIN CONFIDENCE = 0.6

Performance: We tested our model on 1417 images. In blue the occupied parking spots and in green the unoccupied ones can be observed. Here the accuracy score is given based on the detected cars and theallotted parking lots. The metrics obtained for MaskRCNN pre-trained on COCO dataset are:

- Accuracy = 0.82
- mAP (mean average precision) = 0.51

Fig. 7. Inference on an image from PKlot dataset (2013-03-30-12-50-07.jpg)

VII. FUTURE SCOPE AND CONCLUSION

With an exponential increase in population and urbanisation, vehicular traffic is rapidly increasing with more number of vehicles and less parking spaces. The decreasing efficiency of modern busy parking lots are leading to traffic congestion, wastage of time, environmental pollution and potential accidents. Hence, the proposed "Using Mask RCNN to build a deep learning-enabled Smart Parking Model" will overcome all of these drawbacks and will provide aremote facility to users to find a parking slot for a vehicle. Use of camera improves accuracy, provides anti-theft security, increases coverage ofarea and makes the system cost efficient. The proposed Smart Parking model is easy to use and can be deployed on any smart screen having access to internet, it doesn't involve installation of any application. The model's performance is good on the test dataset provided from the PKlot but the model does not perform well on a test dataset different from the views angle and the parkings. The model is overfitting to the PKlot dataset. We can train and fine tune the model from scratch on more varying dataset with complete annotation to help our model generalize and gain in accuracy. The deep Learning model when deployed at fog nodes can help reduce latency issues and minimize the network usage as testing of data is faster in locally deployed models compared to Cloud server based models whereastraining of data is faster through cloud computing as it enables use of GPUs. For future works, another approach using image processing with OpenCV to detect parking spots dividers, asso can detect the position of all available parking spots. Then identify if the parking spot is vacant or occupied using Mask RCNN to detect the car and then calculate the IOU to see if the box of the car matches the parking place can be developed and work on improving accuracy of existing Mask RCNN based parking system can be performed. Alightweight encryption for cloud server can also be developed to improve the security of the system.

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