A Novel Intelligent Image-Processing Parking Systems

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Abstract. The scientific community is looking for efficient solutions to improve the quality of life in large cities because of traffic congestion, driving experience, air pollution, and energy consumption. This surge exceeds the capacity of existing transit infrastructure and parking facilities. Intelligent Parking Systems (SPS) that can accommodate short-term parking demand are a must-have for smart city development. SPS are designed to count the number of parked automobiles and identify available parking spaces. In this paper, we present a novel SPS based on real-time computer vision techniques. The proposed system provides features including: vacant parking space recognition, inappropriate parking detection, forecast of available parking spaces, and directed indicators toward various sorts of parking spaces (vacant, occupied, reserved and handicapped). Our system leverages existing video surveillance systems to capture, process image sequences, train computer models to understand and interpret the visual world, and provide guidance and information to the drivers.

Keywords:
Smart Cities, Car parking, Image Processing, Edge detection, Object Recognition

1 Introduction

By 2050, with the urban population more than doubling its current size, nearly 7 of 10 people in the world will live in cities [1]. Cities are major contributors to climate change. According to UN Habitat, cities consume 78% of the world's energy and produce more than 60% of greenhouse gas emissions. Yet, they account for less than 2% of the Earth's surface [2]. With regard to the United States, about 82.66% of the total population lived in cities and urban areas in 2020 [3]. As an impact of the growth of urban population, the number of land transportation vehicles in US has been increasing significantly.

Along with the increase of urban population, traffic jam and the number of parking spaces in many densely populated cities in the US become more

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problematic. Particularly in public places, the limited parking slots lead car drivers to slowly cruise the city, generating large amounts of exhaust emissions and creating traffic congestion. In addition, 86% of drivers face difficulty in finding a parking space in multilevel or geographically distributed parking lots [3]. Insufficient car park spaces lead to traffic congestion and driver frustration. Improper parking is also another parking-related issue that occurs when a driver parks on or outside of the lines of a parking space. This matter annoys other drivers and most of the time a driver who wants to park in a small leftover slot will give up and feel frustrated.

Although Closed-Circuit TeleVision (CCTV) systems help monitor parking, manually inspecting videos to recognize unauthorized parking behaviors is tedious and inefficient. Not only does it obstruct traffic and cause inconvenience, illegally parked vehicles pose economic risks [4]. Moreover, safety in parking and the need for real-time parking monitoring require the employment of applications and tools that track and record continuous activities including traffic and occupancy.

Potential solutions, such as adding more infrastructure and parking spaces, are not feasible due to the high cost and limited supply of commercial real estate in cities. Therefore, it is crucial to leverage technology advances and develop smart solutions to help drivers quickly locate unoccupied parking spaces. Implementing such smart systems will help resolve the growing problem of traffic congestion, wasted time, money, and energy. It will provide better public service, reduce car emissions and pollution, improve city visitor experience, increase parking utilization, and prevent unnecessary capital investments.

In this paper, we propose a novel image-processing Parking System, called Smart Park, to meet the critical short-term parking demand. Smart Park aims to convert traditional parking lots equipped with video surveillance systems into smart ones. The contributions of our work are: (1) monitor parking space utilization, (2) improve driver experience while decreasing drivers' frustration, (3) enhance parking lots security through number plate recognition, (4) collect valuable data for efficient parking management and informed decision making, and (5) assist drivers and recommend parking lots with respect to the spatio-temporal characteristics of an activity.

To validate and verify Smart Park, we modeled, analyzed, and experimented it on a selection of parking lots. Considering the complex spatial distribution of the parking lots, academic, administrative, service, health, and housing buildings, there is a critical need to provide a user-friendly platform to monitor, secure and efficiently navigate the campus for commuting students, faculty, staff, and visitors.

The reminder of the paper is organized as follows: Section 3 provides an extensive literature review of existing SPSs. Section 5 details Smart Park underlying software requirements engineering and software architecture and design models. Section 6 provides an overview of the obtained results. Finally, Sections 7 and 8 discuss the proposed SPS, highlight its advantages and limitations and conclude with future work.

2 Problem Statement

2.1 Difficulty in Finding Vacant Spaces

Quickly finding a vacant space in a multilevel parking lot is difficult if not impossible, especially on weekends or public holidays. A recent study shows that 86% of drivers face difficulty in finding a parking space in multilevel or geographically distributed parking lots [5]. Finding spaces during weekends or public holidays can take more than 10 minutes for about 66% of visitors. Stadiums or shopping malls are crowded at peak periods, and difficulty in finding vacant slots at these places is a major problem for customers [6]. Insufficient car park spaces lead to traffic congestion and driver frustration [7].

2.2 Improper Parking

If a car is parked in such a way that it occupies two parking slots rather than one, this is called improper parking. Improper parking can happen when a driver is not careful about another driver's rights. Sometimes improper parking occurs when a driver parks on or a bit outside of the lines of a parking space. The driver may notice his improper parking after leaving his car, but may not be willing to unlock his car, restart it, and adjust it to be inside the lines. This matter annoys other drivers and most of the time a driver who wants to park in a small leftover slot will give up and feel frustrated. Figure1 presents an improper parking situation.

2.3 Parking Fee Processing

Parking fee payment can be a time consuming activity for people. Since many current payment machines just accept small notes and coins, finding the exact amount and queuing for payment is not pleasant for drivers. Therefore, providing services that make payment convenient is desirable. One survey showed that queuing up for payment and finding coins for parking fee payment is troublesome. Moreover, most respondents agreed that using Touch'n'Go (a system that allows simply swiping a card and deduct fees from inside credit) is useful and will decrease queue up time[6].

2.4 Unauthorized Parking

Unauthorized or illegal parking is a ubiquitous problem in urban areas. Although many public areas have installed video surveillance systems (also knows as Closed-Circuit TeleVision (CCTV)) to help monitor the traffic conditions, manually inspecting these videos to recognize unauthorized parking behaviors is extremely tedious and inefficient [8]. Not only does it obstruct traffic and cause inconvenience to other drivers - particularly to those who need handicapped parking (HP) - illegally parked vehicles pose great economic risks [4].

2.5 Real-Time Parking Monitoring

Real-time monitoring is the employment of applications and tools that track and record continuous snapshots of your network's overall performance. Organizations use real-time monitoring to track network activity, improve network security, and identify potential problems as soon as they arise. Every business, regardless of size, can benefit from monitoring their network in real time.

2.6 Secure Parking

Secure Parking means an area to which cars can be parked in a secured place where there is on doubt of theft or stealing. Secured Parking should be interpreted by most as either being enclosed within walls and locked – or having security guards on permanent surveillance to protect the vehicles in an enclosed area.

3 Overview on vehicle detection in parking systems

The quality, efficiency, cost, and complexity of a smart parking system depends on the adopted detection technology [9]. Three types of detection technology, vision-based, sensor-based, and artificial intelligence-based are discussed in this section. Vision-based methods use CCTV — usually one camera is responsible for more than one parking space — and image processing software to detect parking space status. Sensor-based methods use one sensor for each individual parking space and might involve Global Positioning Systems (GPS), Global System for Mobile (GSM), or Bluetooth technologies. Finally, Artificial intelligence-based include solutions that involve multi-agent systems, machine learning, deep learning, fuzzy logic and neural network technologies.

3.1 Sensor Based SPS

Wireless Sensor Network (WSN) based SPS WSN can be defined as a network of wirelessly connected sensor nodes that are spatially dispersed and are dedicated to monitoring different environmental aspects such as sound, temperature, pressure, etc. WSN based sensor node comprises various sensors connected to monitor different aspects of the environment. In WSN, all the sensor nodes are connected to a sink node via wireless connection [10]. Nowadays, WSN has received outstanding traction among the SPS developers for flexibility, scalability, and low deployment cost.

Vehicular Ad-Hoc network (VANET) based SPS VANET is based on the Mobile Ad Hoc Network (MANET), where a wireless network of mobile devices is used. SPS utilizing VANET has three main components: Parking Side Unit (PSU), Road Side Unit (RSU), and On-Board Unit (OBU) [11]. The OBUs are installed on the vehicles, PSUs are installed on parking areas, and RSU's are installed beside the roads near the parking areas. This type of system requires a trusted authentication authority that authorizes the vehicle's OBU. If a vehicle is parked inside of a smart parking facility, the OBU of the vehicle provides information to the PSU that the parking lot is booked. Then, this information is transferred to the RSU from the PSU. The vehicles traveling by that road where the RSU is placed can get the information of parking lot occupancy through their OBUs. VANET based smart parking systems are commonly deployed in both closed and open parking lots.

Internet of Things (IoT) based SPS IoT is the buzzing technology of the current era, where all devices are interconnected with one another through the internet. These devices can be computational devices, mechanical devices, and digital devices. They can transfer data to without human-to-human or human-to-computer interaction [12]. IoT technology acts as one of the primary key technologies that developers use for SPS. In IoT-based SPS, all the sensors and computational devices are connected through the internet and can transfer data without any human intervention. The internet connection among sensors, computational devices, and storage units can be either through a wired connection or through a wireless connection.

Global Positioning System (GPS) based SPS GPS is an essential component of different smart parking approaches. But GPS alone is unable to gather parking lot occupancy status and provide other smart parking facilities. However, GPS can provide a vehicle guidance facility for the user to drive towards vacant parking lots. From GPS data, many systems can forecast parking lot occupancy and road traffic congestion using CNN or DL algorithms [13]. The accuracy of GPS depends on the number of receivers it has. For a single frequency receiver GPS, the accuracy is around 7.8 m. On the other hand, a two-frequency receiver provides around 0.715 m of accuracy. The GPSdata is also prone to error if operated inside of a closed parking area. Thus, smart parking systems that use GPS are suitable for open parking lots [14].

Global System for Mobile (GSM) based SPS GSM is a standard for second-generation (2G) digital cellular networks. GSM standard provides a subsidiary service called SMS. SPS, based on GSM, uses SMS service to reserve parking spots at different parking spaces. Some system also generates unique codes for the users during the reservation process, which are used to authenticate the reservation and ensure that only the designated persons get to park [15].

Bluetooth based SPS Bluetooth is a wireless communication technology standard that enables data transfer within a short-range. A smart parking system that is wholly based on Bluetooth technology usually has automated valet parking installed. Regular SPS, which does not deploy an automated valet parking facility, requires additional sensors and approaches to get different smart parking facilities [16]. Many smart parking systems use the Crowd-sensing method to gather information about available parking spots in an area. The method uses smartphone sensors (such as Accelerometer, Gyroscope, Magnetometer, and GPS) and applications to gather parking lot information [17].

3.2 Artificial Intelligence Based SPS

Multi-Agent System (MAS) based SPS MAS is a self-organizing computer-based system accumulating multiple intelligent agents to solve problems that are pretty difficult for any single system to solve [18]. To develop SPS, various researchers have deployed MAS due to its effectiveness in both closed or indoor and outdoor or open parking lot areas. A significant portion of MAS-based SPS provides computing facilities to the agents, which reduces the data transmission head of the whole system. As a result, the power consumption rate decreases.

Machine learning (ML) based SPS ML is a subset of AI that provides a system the ability to learn and improve on a particular task from the datasets or experiences without explicitly programming the system [88]. A machine learning-based SPS analyses the parking lot of data to extract the parking lot status. More- over, ML and AI-based SPS can predict parking lot occupancy status of the upcoming days, weeks, or even months and provide a dynamic pricing scheme. ML-based systems can monitor traffic congestion of particular roads and offer a smart solution to smart parking spaces [19].

Deep learning (DL) based SPS DL is a subset of ML and a function of AI which mimics the human brain in terms of data processing and feature extraction to make decisions [20]. DL algorithms detect vacantly occupied and special parking lots in an SPS instead of regular sensors, which reduces the number of sensors and cameras required by the system. DL is also used to predict parking lot occupancy.

3.3 Neural Network (NN) based SPS

NN is a combination of algorithms that extracts features and under- lying relationships from sets of data through a process that mimics human brain function [21]. In SPS, NN is used for license plate recognition using real-time video data. CNN and machine vision are implemented to detect parking lot occupancy status. CNN's are also capable of providing road traffic conditions of different routes [22].

Fuzzy logic based SPS Fuzzy logic is a reasoning method that resembles human reasoning. It uses multi-valued logic, which means there is no absolute truth or ab- solute false value in fuzzy logic [23]. Fuzzy logic is used in SPS for predicting parking lot occupancy status. But the accuracy of the prediction model based on Fuzzy logic would not be that high without validating the prediction result with the real-time data. Therefore, Fuzzy logic, along with machine vision or sensors, improves the accuracy of the overall system [24].

3.4 Computer Vision/Image Processing based SPS

Computer vision/Image processing based SPS uses different types of camera networks to use image data to extract different information such as parking lot occupancy status, license plate recognition (LPR) and face recognition for billing, security issues, and to provide road traffic congestion report [25]. The systems based on computer vision/image processing technologies usually have a high data transmission rate from the camera network to the processing units because these systems are dependent on real-time parking lot video data for feature extraction [26]. These sorts of SPSs are usually suitable for open parking areas because a single camera can capture a significant area in the parking lot. However, these systems are prone to occlusion, shadow effects, distortion, and changing of light.

4 Methodology

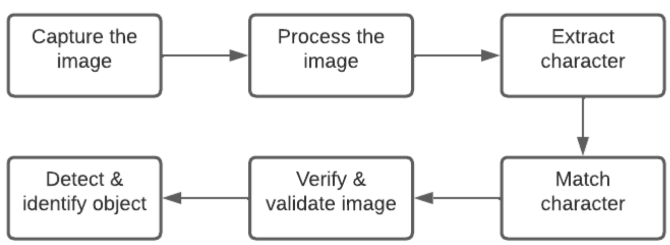

Fig. 1: Methodology Diagram

The process of availability detection relies on the following multiple-step methodology as shown in Figure 1.

1. *Capture the image*: To continuously get the parking lot status, the proposed system takes the live feed from pre-installed monitoring cameras. The cameras are connected to FTP Servers.
2. *Process the Image*: The live feed is then pre-processed frame by frame to reduce the noise using Gaussian blur combined with grayscale filtering techniques.

3. *Extract characters*: To recognize the characters on license plate, the proposed system applies Image Segmentation technique. It extracts the value channel from the HSV format of the plate's image. HSV is a cylindrical colour model that remaps the RGB primary colours into dimensions that are easier for humans to understand. Next, it applies adaptive thresholding on the plate's value channel image to reveal the characters of the image.
4. *Match characters*: After extracting the characters separately for character matching, the proposed system uses Optical Character Recognition (OCR) [27] to recognize the character one by one. OCR comes with pre trained model to classify the characters from the images.
5. *Verify and validate images*: After classifying characters, the predicted characters are validated with the test data. Such a validation is done by taking the output of an OCR run for an image and comparing it to the original version of the same text. The verification and validation include character level accuracy as well as word level accuracy.
6. *Detect and identify objects*: After Verifying and validating the image, the proposed system identifies the object using colour processing which are use as primary filtering to eliminate the unrelated colour or object in the image. Besides that, shape detection use the edge detection (Circular Hough Transform (CHT)). Finally, to detect objects, the system uses Deep learning techniques (Convolutional Neural Networks) to automatically learn an object's inherent features and characteristics.

5 System implementation

In this section, we detail the followed steps to support the Software Development Life-Cycle (SDLC) of the proposed Smart Parking System. First, we present the software requirement engineering process and highlight the key system requirements. Next, we provide an overview on the system design and architecture.

5.1 Software Requirements Engineering

The proposed Smart Parking System has been designed from the perspectives of requirements identified by two key actors; (1) User (Car Driver) and (2) Public Safety (Police). Moreover, with respect to the complexity of SPS, several services are also involved for image processing and data analysis and prediction. The use case diagram depicted in Figure 2 shows how different users with different roles interact with the system.

Requirements describe the characteristics that a system must have to meet the needs of the stakeholders. These requirements are typically divided into functional and non-functional requirements. Functional Requirements [FR] describe how a software must behave and what are its features and functions. Non-Functional Requirements [NFR] describe the general characteristics of a system. They are also known as quality attributes. The following is a selection of functional requirements:

Table 1: Business Use Case Scenarios

<table>
<tr>
<td>Use case Name: View Current Availability
Preconditions: Image processing has been completed and data has been sent to the app for formatting.
Main Sequence:
1. Images are collected from parking lots
2. Images are analyzed using object detection libraries to determine availability
3. Results are sent to the app and are displayed as a heat map
4. User opens the app and views parking information
Exceptions:
1. There is no parking data to be viewed Solution: User is prompted to login instead of register
2. The app cannot connect to the server Solution: Alert the user that there is an error with communicating to the server
Outcomes: The user is able to open the app and view parking availability for different parking lots.</td>
<td>Use case Name: View Future Predictions
Preconditions: Image processing has been completed and data has been fed through prediction algorithms.
Main Sequence:
[topsep=0pt]Images are collected from parking lots Images are analyzed using object detection libraries to determine availability Data is recorded and fed to prediction algorithms Prediction algorithms use past and present data to create parking availability predictions Forecast results are displayed
Exceptions:
[topsep=0pt]User opens the app and views future predictions Solution: Alert the user that there are currently no predictions The app cannot connect to the server
Solution: Alert the user that there is an error with communicating to the server
Outcomes: The user is able to open the app and view future predictions of parking availability for different parking lots.</td>
</tr>
<tr>
<td>Use case Name: Receive Parking Violation Notices
Preconditions: Automatic Number Plate Recognition (ANPR) scans license plates as cars drive into parking lots.
Main Sequence:
[topsep=0pt]ANPR localizes plates in images and performs Optical Character Recognition (OCR) to read license plate numbers Captured plate numbers are compared to the parking permit database Observed violations trigger a message to the campus police department and to the owner of the vehicle
Exceptions:
[topsep=0pt]No parking violation occurs Solution: No action is taken The app cannot connect to the server
Solution: Alert the user that there is an error with communicating to the server
Outcomes: Campus police and users committing violations are notified of said violations.</td>
<td>Use case Name: Report Closures or Other Issues
Preconditions: The user is in the app.
Main Sequence:
[topsep=0pt]User navigates to the report section of the app to chose type of issue and leave a comment Report is received by the server and updates parking conditions based on the information The app is updated to reflect changes
Exceptions:
[topsep=0pt]The user could report false information Solution: Check for similar reports to confirm information and/or manually review the report The app cannot connect to the server
Solution: Alert the user that there is an error with communicating to the server
Outcomes: Users are able to report issues related to parking on campus to cause the app to update information.</td>
</tr>
<tr>
<td colspan="2">Use case Name: Parking Assistant
Preconditions: Image processing has been completed and there is parking availability information in the app to use.
Main Sequence:
[topsep=0pt]User navigates to parking planner in the app and chooses where their class is located. Based on parking availability, user's parking pass type, and parking lot locations, and class location, the app determines optimal parking location. The user is shown a recommendation on where to park.
Exceptions:
[topsep=0pt]Parking availability information is not available. Solution: The user is alerted of this error, and is recommended a parking spot based on location The app cannot connect to the server.
Solution: Alert the user that there is an error with communicating to the server
Outcomes Users are able to find a parking spot closest to their destination based on multiple factors.</td>
</tr>
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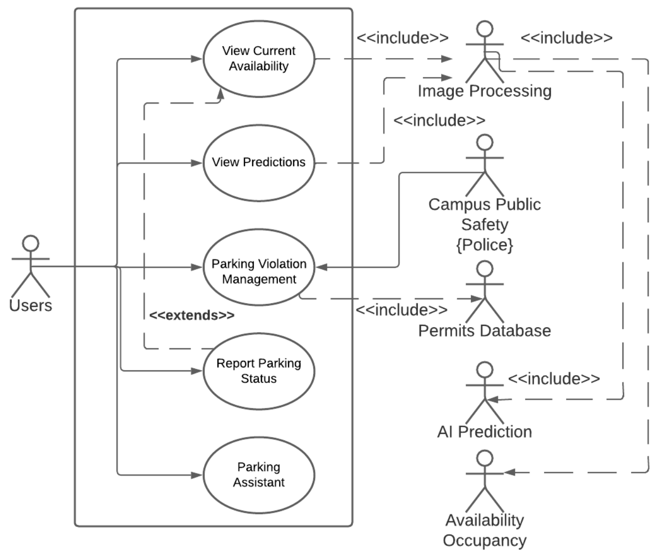


Fig. 2: SPS Use Case Diagram

- [FR1] SPS shall allow users to view current availability in a parking lot.
- [FR2] SPS shall compute and display future predictions to users.
- [FR3] SPS shall detect illegal and unauthorized parking, issue Parking Violation Notices, and allow public safety and users to view and process them.
- [FR4] SPS shall track parking traffic and identify vehicles for parking safety purposes.
- [FR5] SPS shall assist users to identify the best parking considering the location of the scheduled activities.

The above listed functional requirements (FR) have been analyzed and validated with stakeholders and the following set of quality attributes non-functional requirements (NFR) has been derived:

- [NFR1]Performance: SPS will collect CCTV images, process, analyze, and store them every minute to keep parking information relevant.
- [NFR2]Security: SPS will use identification and authentication techniques to read Parking permit registration data and encryption techniques to securely store extracted vehicles identification data.
- [NFR3]Portability: SPS will be mobile accessible through apps and web browsers.

5.2 Software Architecture

The software architecture style of the proposed SPS relies on a service-oriented architecture. The interactions between services are depicted in Figure 3. The components of SPS architecture are:

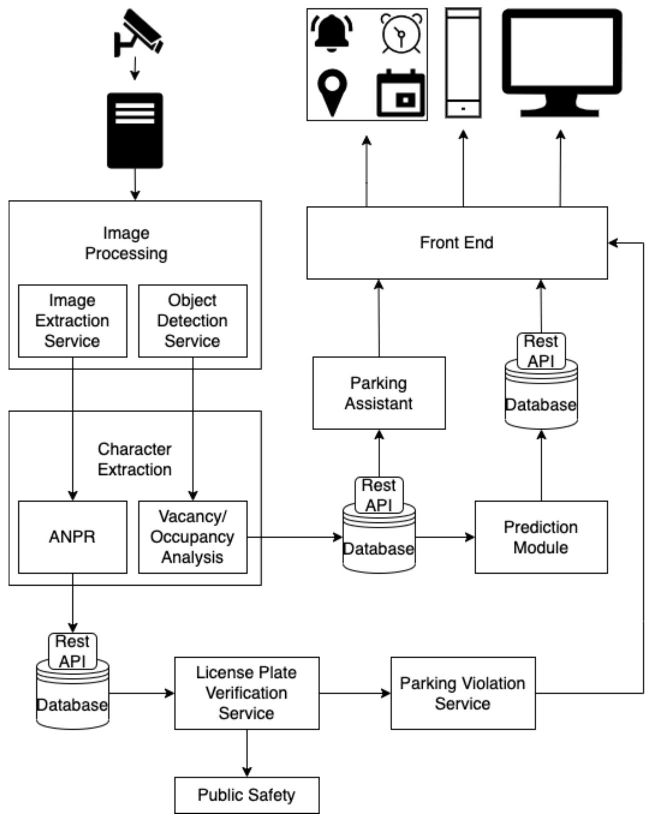


Fig. 3: SPS Software Architecture Diagram

- FTP Server: It gathers parking images from surveillance cameras which are installed in the parking lots.
- Image Processing: The image processing module collects, analyzes and processes data extracted from the FTP Server. This module has two key services:
  - The Image Extraction Service: This service acts as medium to extract the images from the recorded videos which are installed in parking lots.
  - The Object Detection Service: This service is used for the detection of objects. It generates a number n of things and their locations. This service detects and captures the vehicles in the parking spots. Objects include vehicles, parking lines (to detect illegal parking), handicap symbols (to detect unauthorized parking).
- Character Extraction: This module focuses on interpreting images and detected objects.
  - Automatic Number Plate Recognition (ANPR): The ANPR algorithm is applied to extract the plate numbers of the parked cars (See Figure 7). The data collection process consists of accumulating of images and bounding-boxes for training the machine learning model. This module

uses ML/AI based learning techniques using the collected dataset of plate images taken from different positions. The Optical character Recognition (OCR) approach is used to convert images of text into machine-encoded text. The goal is to build a model that can recognize and localize the plates.

- Vacancy/Occupancy Analysis: This service provides information on vacant spots and updates this list as cars enter or leave the parking.
- License Plate Verification: The goal of this phase is to verify and validate plate numbers using the public safety database.
- Parking Violation Service: This service is responsible to issue parking violation notices when improper (illegal or unauthorized) parking is detected.
- Prediction Module: This service extracts the information from the database and predicts the occupancy/availability of the parking based on current status and historical data.
- Parking Assistant: This service provides recommendation about the best parking lot to use while maintaining a trade off between availability and distance/time to a specific location.

6 Results

We designed, implemented, and tested our SPS in 2 parking lots . The existing CCTV deployed system uses FTP compatible cameras. We implemented a web-based application to support our students, staff, faculty, and visitors.

Our SPS successfully detected and reflected the count of parking spots at a rate of 92% accuracy (See Figure 6).

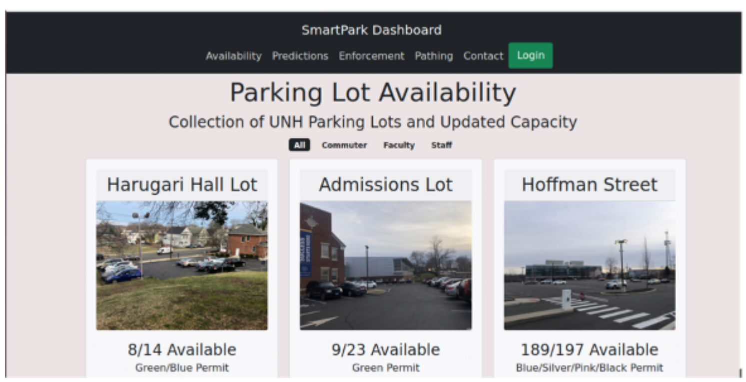


Fig. 4: Smart Park Dashboard: Parking lots availability

We built a prediction model for each tested parking lot to provide a live-feed, compute, and visualize occupancy (Figures 6a and 6b) and a dashboard for

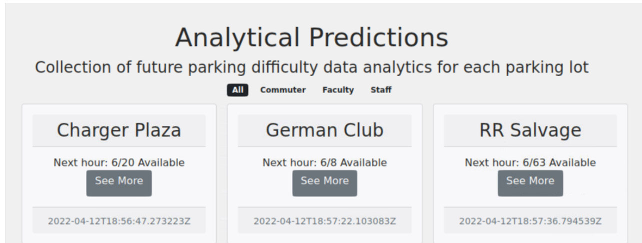
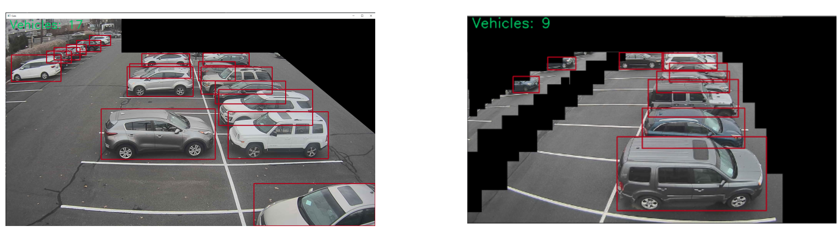


Fig. 5: Smart Park Analytical Predictions Portal

each parking lot which has its own prediction model and Predicted graphs (See Figures 5 and 8).

As far as parking lot monitoring and vehicle identification, we are able to identify and extract local Connecticut license plates information at a 81% success rate (Figure 7).

Thanks to the vehicle identification information, SPS sends a query to the public safety services to verify if a valid parking permit has been issued. We have created a dashboard where we can see all the availability of parking lots (See Figure 4).



(a) (b)

Fig. 6: Smart Park Object Detection and Identification

Finally, our SPS proposes a unique feature: *Parking Assistant*. Considering an activity start time, day of the week, location, and permit type, SPS recommends a parking lot with a convenient walking distance and a high-level confidence of availability.

To illustrate this feature, let us consider the scenario of a course taking place at Kaplan Hall and starting at 8:20am for a user holding a student permit type. First, Smart Park identifies, the parking lots that are at a reasonable walking distance from Kaplan Hall. Next, it computes the availability predictions associated with these lots.

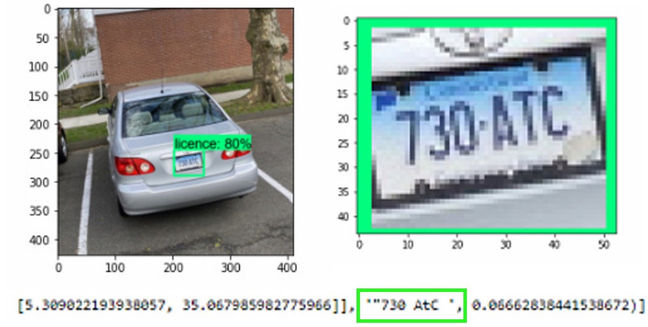


Fig. 7: Smart Park Automatic Number Plate Recognition

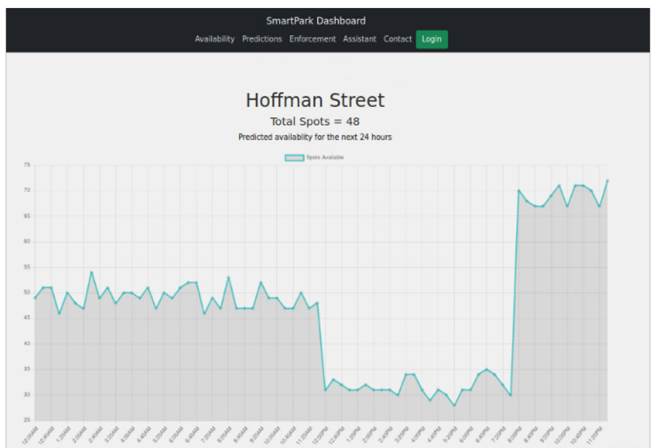
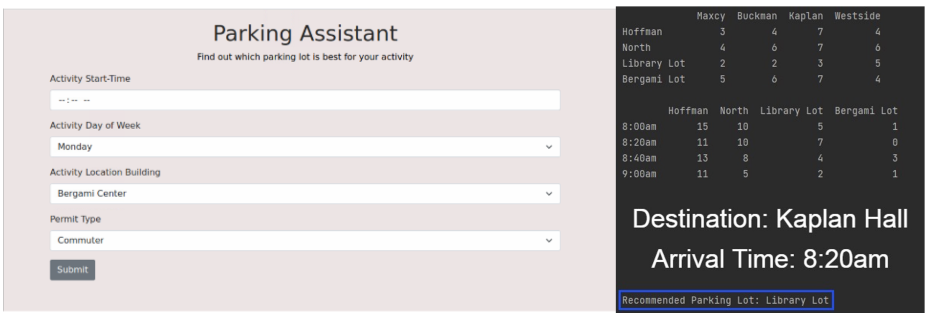


Fig. 8: Smart Park: Predicted Availability Graph

7 Discussion

A number of experiments was conducted and it was confirmed that the image processing algorithms and character extraction techniques work better under good weather conditions, daylight, high contrast between identified objects and their background, and from certain angles of camera view. In fact, under snow or heavy-rain weather conditions, the object detection accuracy can drop as low as 32%. Similarly, the precision of the license plate recognition algorithm drops to 18%. Additional verification and validation will be required to assess the scalability of the proposed solution. Moreover, the machine learning algorithm used to read license plates is trained over a data set of 100's of license plates. it is important to extend the training data set to allow SPS to comprehensively recognize and read US license plates. Although the implemented features of the proposed SPS are quite important and mainly focus on parking lot traffic monitoring, occupancy analysis, vehicle identification and tracking, illegal and unauthorized parking, and illegal parking notice management, there are other value-added features that are still missing such as accident detection in parking lots.



(a) (b)

Fig. 9: Smart Park :(a) Parking Assistant Dashboard, (b) Recommended Parking Lot

8 Conclusion and Future Work

In this paper, an image processing based smart parking system was presented. The proposed image processing based smart parking system has four advantages. First, special hardware infrastructure is not necessary because a CCTV camera can cover large parking spaces. Second, the system can provide an accurate occupancy prediction that is essential for finding the vacant parking. Third, camera-based system can also be applied to the parking lot in the street or residential area. Fourth, the assistant parking feature is a time-space optimization solving that improved parking users experiences. However, such camera-based parking are still vulnerable to accidents that may occur. In this respect, the proposed SPS needs additional features to detect an accident and avoid hit and run situations. Future research following this project will focus on accident detection and processing of parking violation notices. In addition, research to improve the detection accuracy and the processing speed will be performed.

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