License Plate Recognition for Smart Parking Management System Using YOLOv5

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***Abstract*— This study presents a Smart Parking Management System that uses deep learning algorithms for license plate recognition. This study aims to provide an efficient parking system using technological advancement. The study utilizes the You Only Look Once (YOLOv5) algorithm for license plate recognition. It shall detect and recognize the license plate numbers of incoming vehicles. Information is stored in an online database accessible through a web-based application. The YOLOv5 algorithm performs well but is affected by image quality and license plate variations resulting in a 75.13% overall accuracy. The proposed system offers an innovative and efficient approach to parking management, optimizing resource utilization, and reducing costs.**

Keywords— deep learning, YOLOv5, web-based application, automatic boom barrier gate, license plate recognition, smart parking management

I. Introduction

Despite the emergence in technology, parking management systems are still one of the most underrated parties when it comes to automation. Oftentimes, these places are still manually managed. [1] This struggle leads to the 10% to 15% waste of travel time of an average person looking for a parking space, especially in the Metropolitan area [2].

Undeniably, this problem in the parking management system is also visible and prevalent in the Philippines. Indeed, this is one of the issues that arise as a result of a developing metropolis, which is exacerbated by sustained economic growth. A study commissioned by Uber in 2017 revealed that on average, Manila drivers spend 24 minutes looking for parking every day. Consequently, an average of Php 100,000 is lost every year from being stuck in traffic or looking for parking space [3].

In the goal of alleviating this 21st century issue, the researchers developed a program that could optimize the parking management system with the help of machine learning algorithms.

II. RELATED STUDIES

The emergence of modern technology paved the way to smart cities that manage and enhance resources effectively. One of the critical assets that needs to be addressed is the management of parking facilities that cause congestion in urban areas (Farooqi, et. al., 2019). The progress in different aspects of smart cities requires a smart parking management system which is developed to solve parking issues technically and efficiently. The provided overall system architecture and environment is essential in the framework for a complete design. It includes features such as looking for parking spaces, making reservations, paying, receiving notifications, managing data, and monitoring parking conditions. The concepts of the Internet of Things (IoT) can be done by using supportable hardware and sensors to detect parking availability and recognition to control access processes. This study is projected to save money and time in the long run, while also improving a city's people' standard of living. [4]

Cars and other vehicles are reliable tools used by many for transport of goods and getting people in an instant. Due to the increased use of automobiles particularly in metropolitan cities, the need for more efficient parking management. The main challenges that parking systems are facing are lack of proper parking systems, maintenance and response from the maintenance coordinators. To solve this, a Smart Parking System design that allows the user to find an available parking space in the nearest parking area. This proposed scheme utilizes the Iot as well as electronics devices and computers. This study used cloud storage to store the information of the registered user, IP cameras for detecting the plate number of the vehicle, sensors which are placed throughout the parking area and are connected to Raspberry Pi, and Python . In result, the algorithm was able to make use of smart technology and provide a good experience in time saving fuel economy and comfortable ease of access [5]

In the study of Dsouza et al., finding a parking space in a crowded region of an urban city can be very hard. Studies show that an average of 30% of the traffic in an urban city is caused by cars looking for an available parking space. Unavailable parking space is not always the problem but rather the absence of information about the availability of parking space in different parking areas. Many varieties of systems have been proposed to solve the problem of parking. This study proposed to build a computer vision algorithm that can process the video feed of a CCTV camera and detect the available and unavailable parking spaces and to develop a web application aiding the user to find a parking slot, guide the user to the chosen parking spot or to the user's vehicle and online payment. Moreover, to compare the proposed system to other systems. In result, the proposed smart parking system was able to address the issue of parking in an urban setting and aims to solve these with respect to relevant criteria. Furthermore, the proposed system was able to surpass other systems [6].

According to Ebin et al, In large cities parking of vehicles is time consuming and costly. Specially, in a populated area parking is very challenging and risky to avail a free parking space securely. Getting parking lots in cities, especially in heavy traffic, is tough to get a parking slot for drivers. To solve this, an android application for smart parking with efficient space management that includes full automation of paying for parking which will be operated by an Admin was proposed. This proposed system was able to attain high-efficiency car parking in real time and in a short amount of time. In addition, the application provides a secure and reliable way for drivers to park their vehicle [7].

In the study of Khan et. al, a unique parking vacancy slot detection using state-of-the-art detection of vehicles based on Faster R-CNN [8]. Smart Parking Systems can be efficient in managing traffic, especially in cities where vehicle density is high or during rush hours. Parking spot recognition using video feeds from cameras is highly efficient since it does not require any sensors to be installed separately on the parking space. These systems can be extremely beneficial for reducing fuel consumption and as well as cost of maintenance.

The growing number of vehicles has made vehicle management more challenging, emphasizing the importance of license plate recognition technology. While traditional license plate recognition algorithms are effective in everyday scenarios, they struggle to maintain robustness when faced with complex situations such as image distortion and blurring, often resulting in recognition failures. A study by Shi et al., proposes the utilization of YOLOv5 and LPRNet deep learning models for real-time license plate recognition in complex scenes. The YOLOv5 model is responsible for locating the license plate within an image and extracting the detection frame, while the LPRNet model focuses on recognizing the characters on the license plate within the detection frame. By employing deep learning techniques, this approach enhances the accuracy of license plate recognition compared to traditional algorithms. Furthermore, it offers advantages such as a compact model size, high precision, and the ability to be embedded into various systems. [9]

An important application of object detection in smart transportation systems is vehicle detection which aims to extract specific vehicle-type information from pictures or videos containing vehicles. In recent times, ANPR technology has discovered numerous new applications. It is utilized in various areas such as car parking management, towing systems, and vehicle gate entry management. Although ANPR systems are valuable for license plate detection, they encounter numerous challenges in accurately identifying number plates due to variations in size, orientation, and language across different regions worldwide. In our research, we have successfully implemented an ANPR system using a dataset exclusively consisting of number plates with English alphabets and digits. For number plate detection, we have employed the cutting-edge YOLOv5 object detection model. The output of the detection process is then subjected to image processing and contouring techniques to segment individual characters. These characters are subsequently passed through a CNN model that provides the corresponding labels. Finally, these character labels are combined to yield the final output, which represents the vehicle license plate number. [10]

Artificial intelligence is a field that helps in accomplishing challenging tasks for human beings. Image processing is one of the fascinating domains within artificial intelligence. One compelling application in this field is the recognition of vehicle license plates, commonly referred to as automatic license plate recognition (ALPR). Optical character recognition (OCR) methods are frequently employed in such applications. The scope of the Automatic License Plate Recognition system extends beyond parking lots and can be utilized in various facilities requiring control, monitoring, and recording of vehicles passing through specific access points. Examples include private company garages, shopping centers, toll booths, and hospitals, among others. In this paper, we will elucidate our approach in applying two object detection algorithms to develop a system capable of identifying and extracting Moroccan license plates from images. By utilizing transfer learning on YOLOv5 and Faster-RCNN, we trained them using a dataset comprising 724 images of Moroccan registered vehicles. The outcome is a system that can support a parking system by facilitating license plate recognition. [11]

In recent years, the growing number of vehicles has made vehicle management more challenging, emphasizing the importance of license plate recognition technology. While traditional license plate recognition algorithms are effective in everyday scenarios, they struggle to maintain robustness when faced with complex situations such as image distortion and blurring, often resulting in recognition failures. This paper proposes the utilization of YOLOv5 and LPRNet deep learning models for real-time license plate recognition in complex scenes. The YOLOv5 model is responsible for locating the license plate within an image and extracting the detection frame, while the LPRNet model focuses on recognizing the characters on the license plate within the detection frame. By employing deep learning techniques, this approach enhances the accuracy of license plate recognition compared to traditional algorithms. Furthermore, it offers advantages such as a compact model size, high precision, and the ability to be embedded into various systems. [12]

III. METHODOLOGY

A. YOLOv5

The researchers developed a training model that is suitable to be used for RESPARKMAN in identifying the plate number of the car to activate the Boom Barrier Gate. This includes data acquisition, data processing, and choosing of algorithms to build the model.

Gathering of Datasets

Datasets of various plate numbers for optical character recognition in the form of pictures were gathered. The data is stored in the main folder named "plate number" which would be accessed by the model when the training starts. This folder shall contain all possible plate number styles available in the Philippines.

Data Wrangling

In order to organize large quantities of data, subfolders are needed to segregate the different styles of plate numbers available in the Philippines. By segregating these data into different categories and by making their sizes identical, the data access would become easier.

Model Training

The model shall aim to predict the characters in the plate number so that when the algorithm is deployed, it would be able to identify the user by the plate number of the car. This can be done by finding the best fit of weights and biases that shall be used in the algorithm. Model training makes the accuracy range higher and training loss reduced.

Algorithm Tuning

Changing the parameters of an algorithm can yield different results. In this part, a trial-and-error process was done to find out which settings in the hyperparameters of the algorithm are best fit for the algorithm.

Out-of-sample Testing

Statistical data are split into two, an in-sample period and out-of-sample period. An in-sample period is used to create a parameter on which the model is expected to perform, while the out-of-sample testing is used to test the viability of the model in real life scenarios. A separate folder containing pictures of different plate numbers that was not used to train the model is to be used to know if the model is accurate enough to recognize the characters. It will also be at different angles to further test its accuracy.

B. Automation of Boom Barrier Gate

The automation of the boom barrier gate involves a systematic methodology to ensure efficient access control. It begins with selecting a suitable boom barrier gate mechanism based on factors such as durability, reliability, and compatibility with the overall system. The boom barrier gate is integrated with the license plate recognition system to enable automated access authorization. An ultrasonic sensor is installed as a safety measure to detect whether the entering vehicle has passed the gate. Additionally, the system is equipped with mechanisms for real-time communication between the license plate recognition system and the boom barrier gate, allowing for seamless access control. Extensive testing and fine-tuning are conducted to ensure accurate and timely gate operation, minimizing false positives or negatives.

The circuit diagram of the automatic boom barrier is given below.

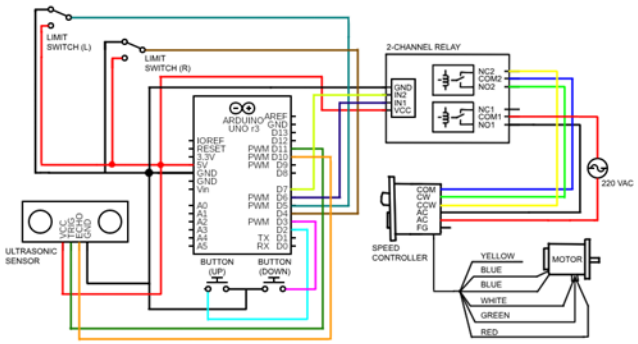

Fig. 3 Circuit diagram of automatic boom barrier gate.

The license plate detection system operates seamlessly in real time, constantly scanning for license plates. Upon successfully detecting a verified license plate, a serial message is promptly transmitted to the Arduino, enabling efficient access control. In response, the relay is activated, setting the motor in motion to open the gate and grant entry. The motor stops when the right limit switch is pushed. The system then waits for a flag status change from the ultrasonic sensor which would indicate the passing of a vehicle. As soon as a vehicle passes, the gate goes down after a short interval. Similarly, the motor stops as soon as the left limit switch is triggered. Two push buttons are installed as an alternative manual control for the boom barrier.

C. Processing Unit

The processing unit plays a crucial role in handling the computational tasks involved in the system. The unit is equipped with a computer powered by a 6-core, 12-thread AMD Ryzen 5 4600g processor operating at a base clock speed of 3.7 GHz. It also features 16 GB of 2666 MHz RAM configured in dual-channel mode and a GTX 1660 Super graphics card. The computer includes a 512 GB SSD and operates on the Windows 10 operating system. The processing unit serves as the central hub for executing the YOLOv5, which heavily relies on the GPU for efficient and parallel processing. Additionally, a 2K-resolution webcam is connected to the computer to capture license plate images for processing. This robust processing unit ensures the efficient and timely execution of the algorithms, contributing to the overall performance and effectiveness of the system.

Fig. 4 Computer Setup for the system.

D. *Web-based Application*

The researchers have developed a web-based application for administrator and security employees to see and monitor the entry logs of the vehicles in the establishments. In addition, the administrator, security employees and customers of the establishment can see and monitor the real-time situation of the parking lots. This application also has an in-app payment system for the users and customers to be able to pay after reservation.

Building of the Web-based Application

The researchers followed the Model View Control architecture when building the web application. With this, the web framework shall provide (1) an abstraction model over the relational database through object relational mapper which transferred the programming language code into an SQL code which was used by the database, (2) routing for mapping URLs in the browser to the codes that shall run on the server; and (3) a way of directly entering data from the database to the HTML for the user interface.

Considering this, the researchers chose PHP which is a free, open-source and battery-included web framework that has a lot of built-in features, libraries and packages.

Development of a Database Management System

The researchers created a relational database management system, and used MySQL which is a free and open source query language based on SQL used for communicating with the database.

E. *User Acceptance Testing*

Acceptance testing is a critical step in a software development process in which a user analyzes and ascertains other's work for the purpose of accepting it. It can be categorized in different ways such as User Acceptance Tests *(Internal Alpha Tests and External Beta Tests),* Operational Acceptance Tests, Regulatory Acceptance Tests and Contract Acceptance Tests. The objective of user acceptance testing is to seek reassurance for some reasons including presentation, demonstration, probing, usability and validation.

Method of Analysis

The researchers used the User Acceptance Test (UAT) to assess the software. Consequently, a survey using Likert's Scale acceptability test was conducted in accordance with ISO 9126 standards for software quality model which identifies six main quality characteristics specifically functionality, reliability, usability, efficiency, maintainability and portability.

Participants and Setting

The respondents should fall under one of the four sub groups or categories which include (1) professionals in the field of technology such as Information Technology, Web Development, Computer Science, Software Engineering and other related fields pertaining to technology; (2) stakeholders who are working on the parking industry; (3) graduates and graduating students with course related to the field of technology, like Bachelor of Science in Electronics Engineering; and (4) owners of private vehicles who use their car for everyday life mobility such as going to work or school, going to the mall and other places.

Collection of Data

With the use of controlled quota sampling, the researchers distributed the survey questionnaires to the selected respondents corresponding to the given four categories in Metro Manila, Philippines. They were chosen based on the researcher's necessary target data for acceptability testing and convenience

Statistical Analysis

The researchers analyzed the results through determining the weighted mean of each item in every category to evaluate and analyze the data and/or result of the UAT adapted from the study of A. Abran [13]. Each range of the scale corresponds to the following interpretation:

RANGE	INTERPRETATION
1.00 - 1.79	*Strongly Disagree*
1.80 - 2.59	*Disagree*
2.60 - 3.39	*Neutral*
3.40 - 4.19	*Agree*
4.20 - 5.00	*Strongly Agree*

TABLE I. RANGE AND INTERPRETATION OF DATA

IV. RESULTS AND DISCUSSION

YOLOv5 allows us to efficiently locate and extract license plate information from real-time video streams. To extract the alphanumeric characters of the license plates, a Python library called EasyOCR is used for character recognition.

	Plate Number	Accuracy	Weight	Weighted Accuracy	First Corrected Frame
1		0.8	30	24	4
2		0.38806	67	26.00002	3
3		0.956522	23	22.000006	1
4		0.714286	21	15.000006	1
5		0.904762	21	19.000002	3
6		0.761905	21	16.000005	2

TABLE II. YOLOv5 REAL-TIME ACCURACY

TABLE II shows results of the successfully recognized plate numbers by the system. There are sixteen (16) license plate numbers captured by the camera sensor installed on the boom barrier gate.

To calculate the accuracy rate for the license plate detection system:

$$Accuracy = TP/N$$

where:

TP (True Positives) = the number of frames with correctly identified license plates

N = the total number of frames processed

This yields an overall accuracy of 75.13% showing that the system can extract the correct text from the plate number. The speed of the license plate detection system is calculated as:

$$Speed = AP * (APT + ADT)$$

where:
AP (Average Position) = the average position of the first correct frame

APT (Average YOLO Processing Time) = the average time taken by the YOLO model for processing a single frame

ADT (Average Database Access Time) = the average time taken for cross- checking the output with the database.

Overall the system was able to achieve a 75.13% accuracy rate. The license plate numbers are cross-checked on an online database which requires the system to continuously read and process license plates until a registered plate is recognized. With this, during testing, the system was able to accurately detect the license plate within the first processing of an average of 2.31 frames.

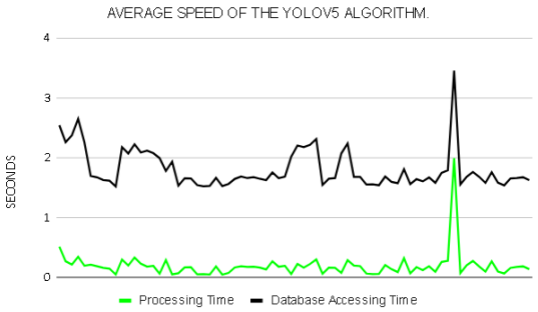

Fig. 5. Average speed of the YOLOv5 algorithm.

Fig. 1 shows the speed of the YOLOv5 algorithm. The average processing time of the algorithm per frame is 0.19 seconds. And the average time it takes for the system to cross-check the plate with the database is 1.81 seconds. This means that the system is able to authorize a vehicle in an average of 4.62 seconds upon entry. These figures highlight the efficiency and effectiveness of our license plate recognition system.

The web application displays the availability of each parking slot in a parking space. The web application is designed to be responsive, making it accessible to both desktop and mobile devices. It contains four types of account: the admin, security, accounting and user account.

In order to evaluate the functionality of the web application, a user acceptance test was conducted, implementing the ISO 9126 standard as the basis for the evaluation.

TABLE II. UAT Results

Criteria	Total (N = 25)	Interpretation
	Mean	
Functionality	4.36	*Strongly Agree*
Reliability	4.36	*Strongly Agree*
Usability	4.58	*Strongly Agree*
Efficiency	4.43	*Strongly Agree*
Maintainability	4.4	*Strongly Agree*
Portability	4.41	*Strongly Agree*

TABLE II shows the result of the user acceptance test. Based on the given results, the respondents showed a positive response as all of the given criteria for quality standards rooted from the ISO 9126 standard garnered a mean of 4.36 to 4.58 (*Strongly Agree*). This suggests that the software quality can adhere to the need of standardized Smart Parking System as it has the potential to provide a comfortable ease of access as stated by Kanteti, D. et. al. [5] and shows good reliability that may help the drivers in parking their vehicles [7].

Consequently, as it earned a strong agreeable rate, the software has a tendency to address the issues of parking systems in urban areas [6] and the congestion it brings in the busiest part of the community [4].

V. CONCLUSION

This study utilized YOLOv5 with EasyOCR to automate the parking management system. The plate detection system uses YOLOv5 with EasyOCR. This results in an overall accuracy of 75.13% which successfully identifies the plate number of the vehicles. By utilizing advanced technologies such as camera sensors and boom barrier gate automation, the system achieves efficient and automated parking management. The camera sensors enable accurate license plate recognition, enhancing security and access control. The boom barrier gate automation automates the entry and exit process, improving overall efficiency. Moreover, the user acceptance test, conducted based on ISO 9126 standard yielded a mean rating of 4.36 to 4.58 (*Strongly Agree*). This indicates that by incorporating a web-based application, users can effortlessly navigate through various functionalities, make parking reservations, manage payments, and access personalized accounts. The integration of the web-application gives users greater control and flexibility, enhancing their overall parking experience. The application also ensures accurate and up-to-date information, enabling smooth coordination among different components of the parking management system.

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