SMART PARKING MANAGEMENT SYSTEM USING MACHINE LEARNING

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Abstract

The increasing number of cars on the road, especially in congested locations, has made finding parking spaces a significant challenge. This study develops a Smart Parking Management System (SPMS) utilizing machine learning to provide real-time monitoring and management of parking spaces. The system aims to enhance customer satisfaction by reducing the time and effort required to find parking, optimizing parking space use, and reducing congestion. The assessment was carried out with 47 respondents and 3 IT professionals, revealing that the system meets all requirements and offers substantial benefits to users.

Keywords: *Smart Parking Management, Machine learning algorithms, Real-Time monitoring, Parking lots.*

INTRODUCTION

The rapid evolution of technology has significantly impacted various aspects of daily life, including parking lot management. Based on the International Energy Agency (IEA), the global number of cars exceeded 1 billion in 2020, with 80 million new automobiles sold in 2019 (Abbasi & Samsudin, 2017). Modern vehicles have been continuously improved for enhanced comfort, security, and convenience, and electric vehicles are being developed as a sustainable alternative to traditional gasoline-powered cars (Baimakhanova & Tokhtarova, 2019). Despite these advancements, parking management remains a challenge, especially in urban areas.

Parking lots worldwide vary in availability and condition, with some regions implementing advanced technologies such as sensors and mobile applications to track and reserve parking spaces (Huang et al., 2019). Additionally, sustainable construction materials and green infrastructure are becoming more prevalent in parking lot design (INRIX, 2017). The shift towards alternative transportation modes, including electric vehicles and public transit, is also influencing parking management (Japan International Cooperation Agency, 2014).

In the Philippines, the number of registered vehicles reached 4,951,662 units in December 2021 (Li et al., 2021). The growing demand for parking has led to the consideration of off-site parking solutions and the implementation of automated parking systems in urban areas (Onodera et al., 2020). For instance, SM Megamall introduced the first intelligent car parking system in August 2019, reflecting a trend towards more advanced parking management systems (Perera et al., 2021). However, traditional parking management methods still dominate, leading to increased search times and inefficiencies (Shaikh & Chandurkar, 2019).

The City of Angeles faces significant parking challenges due to urbanization, necessitating an automated and efficient Smart Parking Management System (SPMS) to enhance parking efficiency and reduce related issues. Such systems can optimize parking space use, reduce human error, and provide a more convenient parking experience. Overall, there is a need for a technologically advanced approach to parking management to address current issues and improve system efficiency.

Statement of the Problem

The primary objective of this research is to develop a smart parking management system that

accurately displays parking occupancy, availability and improving the efficiency and utilization of parking spaces. The study addresses the following specific problems:

1. The inefficiency of traditional parking systems due to the lack of real-time monitoring.
2. The excessive time required to locate parking spaces using traditional systems.
3. The contribution of parking lots to traffic congestion as vehicle owners simultaneously search for parking spaces.

Objectives of the Study

This study aims to design and develop a smart parking management system utilizing machine learning techniques. Specific objectives include:

1. To have efficient parking management that enhances the customer experience providing real-time information about available parking spaces.
2. To lessen the consumption of time and effort required to find parking by accurately directing drivers to available spaces, allowing for effective parking management.
3. To reduce congestion and optimize parking space utilization, parking lots are decreased through effective parking management, which guarantees that vehicles enter and depart parking facilities smoothly easing congestion and improving transportation effectiveness..

Scope of the Study

The study aims to develop and evaluate the effectiveness of a smart parking system using a combination of cameras and machine learning algorithms. The primary aim is to focus on the development of an algorithm that can accurately detect the occupancy status of parking spots in real-time which will improve the efficacy and accessibility of parking facilities on the school campus specifically tailored for vehicle owners that are students and school personnels. In order to enhance traffic management and maximize parking space utilization, the system will be implemented using cameras to provide comprehensive coverage of the parking lot. The study intends to evaluate the potential advantages of the machine learning model, challenges integrated into the system by the experience of users, and implications of implementing smart parking technology setting to evaluate its effectiveness in improving parking lot efficiency and reducing traffic congestion for various stakeholders.

Significance of the Study

This study determines the advances of smart parking management systems (SPMS). This study provides an in-depth understanding of the edge of machined learning technology. The findings of this study are beneficial to the following:

1. **To the School Personnels.** The results of this study may give school personnels insights on capabilities of Smart Parking Management. This will guide them in discovering new strategies to help students in learning, practicing, and improving their skills and talents.
2. **To the Students**. This study will give them knowledge on advances of Smart Parking Management Systems wherein they will be able to make the campus environment safer for them, especially late at night or in remote places. These features include well-lit parking lots and surveillance cameras. Also, this study will give them a better understanding of the modern parking systems in succeeding on their journey as a student and a worker for future years.
3. **To the Vehicle Owners (Drivers)**. This study will be beneficial to the drivers in reducing the amount of time and frustration associated with searching for available parking spaces. Vehicle owners will also receive positive perception from the improved efficiency and enhance the parking reservation system, which can help to reduce inconvenience rather than

save time and improve overall parking experience.

4. **To the Parking Facility Operators**. The results will help to optimize parking operations by giving parking facility operators access to real-time data on parking space utilization. For the operators, this may mean higher profits, lower expenses, and increased efficiency.
5. **To the Researchers**. The researchers themselves can benefit from the study by gaining experience in designing and implementing a Smart Parking Management System using machine learning techniques. The study can also provide opportunities for publication and dissemination of research findings.
6. **To the Future Researchers.** Future researchers will benefit from the study's theoretical foundation and conceptual framework as they create their own or enhance this study to address parking-related issues.

Conceptual Framework

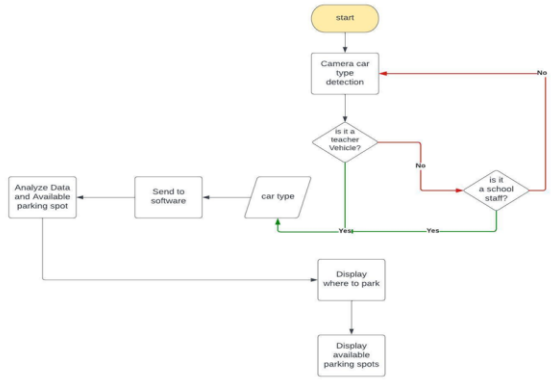


Figure 1. Flow Chart Diagram

The flow chart diagram illustrates the proposed system that operates in real-time, which enables instantaneous detection, analysis of vehicles and parking spots. This functionality is facilitated through the integration of advanced machine learning practices, which enhances the system's ability to detect vehicles and display real-time information on available parking spots. The system further continuously monitors the availability of parking spaces, providing real-time data updates to drivers.

To improve user experience, drivers receive prompt information on the number of available parking spots and recommendations on the most suitable parking location through the monitor. The system's flow is continuous, and data is constantly updated in real-time, ensuring optimal functionality and reliability.

METHODOLOGY

In this chapter, the method employed by the researcher in developing the system is discussed. Additionally, the study's research design, participants, sampling method, instruments, development and validation of the instruments, data collection processes, and analytical tools are described.

Algorithm

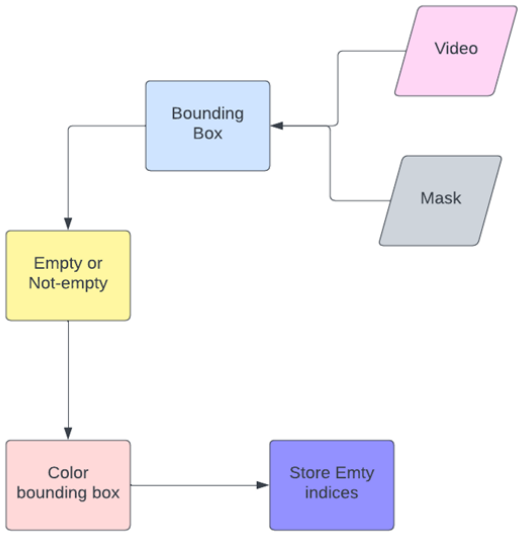


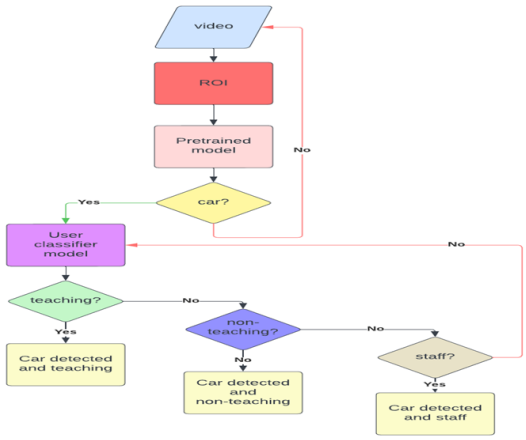
Figure 2. Parking Spot Detection *(PSD) Algorithm for Detecting Available Parking spot*

The Parking Spot Detection (PSD) algorithm is used in the parking lot to detect each parking spot simultaneously. It begins by using a masked image of the parking lot to draw bounding boxes around connected components in the segmented image. The model then identifies whether each spot is empty or occupied. Empty spots are marked with green bounding boxes, while

occupied spots are marked with red. Finally, the program stores the identification of the parking lot along with the indices of the empty spaces.

Figure 2: Object and User Classifier

(OUC)Algorithm for User Detection



The Object and User Classifier (OUC) Algorithm for User Detection utilizes two models: the YOLOv8 pretrained model and a custom user classification model. Initially, a region of interest (ROI) is defined where the YOLOv8 model identifies vehicle types, focusing specifically on cars in the current setup. Flags are then used to continuously monitor whether the detected user falls into categories such as teaching, non-teaching, or staff, based on the school premises. When a vehicle classification is detected, these flags are activated, and the data is subsequently forwarded to the main program for additional processing.

Research Design

In this study, Descriptive Research was employed as the most suitable research method. Descriptive research is distinguished by its primary goal of data collection to address particular issues, allowing researchers to fully comprehend the situation at hand. In order to establish hypotheses and provide solutions, it entails outlining several situations and analyzing the behavior of a sample within a population. This approach works well for addressing queries, reaching sound conclusions, and making recommendations (Atmowardoyo, 2018).

Given the nature of the study, Descriptive Research is the most appropriate approach as it allows researchers to gather essential facts relevant to the proposed study. These facts serve as the basis for making scientific judgments. The researchers aim to address existing parking issues in various areas resulting from inadequate management of parking spaces.

Moreover, quantitative methods will also be employed. This involves the use of surveys to collect numerical data from a sample population regarding their parking experiences and issues. The survey data will then be analyzed using statistical techniques to identify patterns, correlations, and potential causes of parking problems. By integrating quantitative analysis, the study will provide a more comprehensive understanding of the parking issues and enable the formulation of data-driven solutions and recommendations.

Participants

The participants in the study included students and school personnel who drive their own vehicles to and from the school each day. These participants were selected for the study because of their individual experiences and using vehicles for commuting within the school setting. the participant must be currently working or studying in City College of Angeles. The study has 47 Non – I.T. and Three I.T. Experts with a total of 50 respondents.

To choose the participants for this study, a purposive sampling strategy will be used. Using a non-probability selection technique called "purposeful sampling," people are specifically chosen who have certain traits or experiences that are pertinent to the study's goals. In this situation, volunteers who have driving experience and are eager to take part in the study will be specifically picked.

Purposive sampling is frequently used to gather in-depth opinions from people with specific knowledge or experiences. By focusing on participants who can offer useful and pertinent information, researchers can increase the depth and caliber of their research findings (Palinkas, et al., 2015). Overall, this study had conducted with 47 participants.

Procedure

The researcher used the following resources to get the information needed for the suggested system:

1. **Web Researches**

   Web research is now a common method for learning new things in the modern world (Bhat., 2019). In order to obtain pertinent data and gain access to study-related papers, the researcher will use the internet to its fullest extent in this study. By examining current initiatives and studies that offer insightful information about the system, the study can broaden its knowledge base by using web research.
2. **Survey**

   The findings of this study were further evaluated through a survey conducted with participants using Google Forms. The survey aimed to gain a deeper understanding of the system's operation, functionality, and alignment with its intended purpose. It will be distributed to potential system users to seek their insights and feedback, assessing the technical aspects, user experience, and overall suitability.
3. **Evaluation Questionnaire**

   In accordance with ISO-25010 standards, the produced system application's quality is evaluated using a number of product quality parameters. These desirable qualities include functionality appropriateness, performance effectiveness, compatibility, usability, dependability, security, maintenance ease, and portability. The study seeks to ensure that the created system satisfies the specified requirements for each quality element by assessing the web application against these standards.

   a. **Functional Suitability** this measures how well the software's functions align with its intended purpose and requirements. It ensures the software does what it's supposed to do accurately.
   b. **Performance Efficiency** this assesses the software's ability to use system resources effectively, like memory and processing power, to deliver responsive performance and handle workloads efficiently.
   c. **Compatibility** evaluates how well the software can coexist with other systems, software, or environments without causing conflicts or issues.
   d. **Usability** assesses how easily and effectively users can interact with and navigate through the software to achieve their goals.
   e. **Reliability** measures the software's ability to consistently perform its functions without errors, failures, or unexpected crashes over time.
   f. **Security** focuses on protecting the software and its data from unauthorized access, ensuring confidentiality, integrity, and availability.
   g. **Maintainability** looks at how easily the software can be modified, updated, or repaired while minimizing risks and costs.
   h. **Portability** assesses the software's adaptability to different environments or platforms, allowing it to run effectively across various systems or devices.

Data Analysis

Data analysis, which includes the gathering, analyzing, and interpreting of conclusions drawn from raw data, is an important part of this study (Amadebai, 2019). Organizing, evaluating, and coming to intelligent conclusions are steps in the process that guarantee the quality and correctness of the information presented. The study's goal is to effectively meet the research objectives by identifying insights, identifying trends, and drawing reliable conclusions from the examination of the study's data. After the data were gathered, data analysis and interpretation were done using frequency count distribution, percentage distribution, mean, and Likert Scale.

Arithmetic Mean: The technique entails averaging the numerical data gathered (Glen, 2020). It enables the calculation of the average value for each category of data, which can then be interpreted and condensed using descriptive ratings based on their relative rates.

Frequency Distribution: Refers to the representation of individual values or categories as a percentage of the total. It involves expressing each specific value or category in relation to the whole dataset.

Percentage Distribution: In a data representation known as a frequency distribution, the frequencies of different categories are expressed as percentages of the total frequency, which is equal to 100 (Statistics Canada., 2021). The number of observations linked to each data point or set of data points can be understood by this data visualization.

Formula:

$$P = (F/N) \times 100$$

Where:

P = Percentage
F = Frequency
N = No. of respondent

Likert Scale: is a research tool used to measure respondents' attitudes, opinions, and perceptions. Participants rate their agreement with various statements on a numerical scale, allowing researchers to quantify and compare responses.

Table 1. Likert Scale

Numerical Rating	Description
5	Excellent
4	Very Good
3	Good
2	Fair
1	Poor

Table 1 above displays the range of scale values for questionnaires. It was based on how the participants perceived the application's purpose. In the surveys that participants had to fill out after using the application, numerical ratings were present. Different interpretations can be made of each numerical rating.

Likert Scale Interpretation of the Evaluation Result: The results from the testing and evaluation of the system were interpreted to achieve consistent ratings.

Table 2. Likert Scale Equivalent

Numerical Rating	Description
4.20 – 5.00	Excellent
3.40 – 4.19	Very Good
2.60 – 3.39	Good
1.80 – 2.59	Fair
1.00 – 1.79	Poor

Table 2 above displays the descriptive rating scale and precisely explains each numerical rating to ensure respondents' understanding.

RESULTS

The entire set of results is covered in this chapter. It contains screenshots of the system and application outputs as well as the various pieces of hardware that the researchers have used to conduct the investigation. Additionally, the IT assessment outcomes both non-IT specialists and experts.

Evaluation Results

The evaluation outcomes, which include the three IT assessments, were discussed in Tables 3 and 5

of this report. professionals who employ ISO-25010 as a survey instrument for data collection. 47 Non-I.T. and Three IT Professionals, with fifty replies in all. It demonstrated that the majority of participants are experienced drivers of vehicles.

Table 3. Evaluation Results of IT Experts

Criteria	Mean	Descriptive Rating
Functional Suitability	4.56	Excellent
Performance Efficiency	4.44	Excellent
Compatibility	4.33	Excellent
Usability	3.93	Excellent
Reliability	4.42	Very Good
Security	4.27	Excellent
Maintainability	4.20	Excellent
Portability	4.11	Very Good
Overall Mean	**4.24**	**Excellent**

Table 3 presents the evaluation results from three I.T. specialists, showing the mean, ranking, and qualitative interpretation for each criterion. The software performance averaged 4.24, rated as Excellent, indicating user-friendliness, dependability, ease of use, resource efficiency, and manageability, meeting user needs.

Functional Suitability scored 4.56 (Excellent), reflecting the system's accuracy, appropriateness, and completeness in achieving its main objective. Performance Efficiency, with a score of 4.44 (Excellent), demonstrated operational behavior, resource efficiency, and capacity. Compatibility scored 4.33 (Excellent), showcasing appropriateness, learnability, operability, protection against user error, accessibility, and user interface aesthetics. Usability scored 3.93 (Very Good), indicating that both users and evaluators found the system easily learnable and user-friendly, with an attractive GUI.

Reliability was rated 4.42 (Excellent), demonstrating maturity, availability, and fault tolerance. Security, covering confidentiality, integrity, accountability, and authenticity, received a score of 4.27 (Excellent). Maintainability scored 4.20 (Very Good), reflecting modularity, reusability, analyzability, modifiability, and testability. Portability scored 4.11 (Very Good), encompassing replaceability, compliance, simplicity of installation and configuration, and platform compatibility.

In ranking, Functional Suitability was highest at 4.56, followed by Performance Efficiency at 4.44, Reliability at 4.42, Compatibility at 4.33, Security at 4.27, Maintainability at 4.20, Portability at 4.11, and Usability at 3.93. Usability scored highest among Non-I.T. Experts, while Functional Suitability scored highest among I.T. Experts.

Among the metrics that were used in ISO 25010 Usability has the highest score in Non – I.T. Experts while Functional Suitability has a highest score in I.T. Experts.

Table 4. Evaluation Results of Non-IT Experts (Gardeners)

Criteria	Mean	Descriptive Rating
Functional Suitability	4.37	Excellent
Performance Efficiency	4.39	Excellent
Usability	4.44	Excellent
Reliability	4.33	Excellent
Overall Mean	4.38	**Excellent**

Table 4 shows the Non-IT results from 47 respondents in the expert review of the system. The system received an overall mean rating of 4.38, considered excellent. Only four characteristics were evaluated, as the other criteria were difficult for Non-IT experts to assess.

Functional Suitability scored 4.37 (Excellent), indicating the system's appropriateness, accuracy, and completeness in achieving its main goal. Performance Efficiency received a score of 4.39 (Excellent), demonstrating the system's capability, resource efficiency, and operational behavior. Usability scored 4.44 (Excellent), showing that users found the system easily accessible and simple to use, with a visually appealing graphical user interface. Reliability was rated 4.33 (Excellent), proving that the system's fault tolerance, recoverability,

availability, and maturity were successfully achieved.

The program received an excellent rating based on the combined evaluations of its users and IT experts, indicating high program acceptability among participants. A total mean of 4.20 to 5.00 is required to quantify this Excellent rating.

DISCUSSION

This section presents the summary and conclusions derived from the evaluation results. It also includes recommendations from the researchers and some of the IT experts for further enhancement of the proposed system.

Summary Of Findings

In summary, drivers frequently have difficulties trying to find a parking space in a business or nearby parking garage. To address these issues, researchers developed Smart Parking Management Using Machine Learning. This technology helps drivers secure spots in advance, so they do not have to worry about finding parking when they get there. The system received an overall rating from non-IT respondents of 4.38, which is comparable to an excellent rating. This indicates that the public can benefit from and find the Smart Parking Management System using Machine Learning suitable for their needs. and is appropriate for their surroundings and equipped with characteristics that allow it to function in a parking lot.

Lastly, Smart Parking Management System using Machine Learning received an overall rating from the IT specialists of 4.24, which is considered excellent. Three experts' standards were satisfied by the system, indicating that it is suitable for general public usage.

CONCLUSIONS

In conclusion, the development and implementation of a machine learning-powered Smart Parking Management System represents a significant advancement in addressing the challenges associated with parking in a rapidly evolving environment. Many vehicle owners experience long wait times for parking due to the lack of real-time monitoring of available spots, resulting in traffic congestion. By utilizing a Smart Parking Management System, drivers can receive real-time assistance in locating available parking spaces, saving time and reducing the need to search for a spot. This system enables vehicle owners to drive directly to an available space without causing traffic, ultimately saving time and effort.

Recommendations

The researchers recommend enhancing the system's features and architecture based on the study's constraints and participant assessments, including input from three IT experts. They suggest adding a parking option for visitors, considering weather conditions and time of day, and addressing legal implications. Improved data quality, cost management, and collaboration with legal professionals are advised for better real-time data collection and compliance. Financial sustainability through cost-sharing, public-private partnerships, and maintenance programs for equipment are also recommended. Lastly, incorporating security controls and optimizing user adoption strategies are essential for a successful and lasting implementation.

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