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Comprehensive Literature Review on Smart Parking Management Systems

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Abstract- *Smart parking management systems are becoming an important part of smart cities due to the increasing number of vehicles and parking problems in urban areas. Traditional parking systems waste time, fuel, and increase traffic congestion. This paper presents a comprehensive literature review of smart parking systems based on recent research work. Various technologies such as Internet of Things (IoT), wireless sensor networks, image processing, and cloud computing are discussed. These technologies help in detecting available parking spaces and guiding drivers efficiently. The review also focuses on different methods like sensor-based, camera-based, and mobile application-based parking systems. Advantages such as reduced traffic congestion, lower fuel consumption, and improved user convenience are highlighted. However, challenges like high installation cost, data privacy, and system maintenance are also identified. From the literature, it is observed that modern systems are moving towards Artificial Intelligence and machine learning for better prediction and automation. This paper also suggests innovative improvements such as integrating face recognition, dynamic pricing, and smart reservation systems. Overall, smart parking systems can significantly improve urban mobility and make parking more efficient, reliable, and user-friendly.*

Keywords -*Smart Parking, IoT, Sensors, Machine Learning, Smart Cities, Automation*

INTRODUCTION

In recent years, urbanization and population growth have significantly increased the number of vehicles on the roads. As a result, parking has become a major challenge in cities. Drivers often spend a large amount of time searching for available parking spaces, which leads to traffic congestion, fuel consumption, and environmental pollution.

Traditional parking systems are mostly manual and do not provide real-time information. These systems rely on human management and lack efficiency. Due to this, many parking spaces remain unused while drivers continue searching for available spots.

Smart parking management systems are designed to overcome these problems by using modern technologies. These systems use sensors, cameras, and communication networks to monitor parking spaces and provide real-time information to users. Drivers can easily find available parking spaces using mobile applications or digital displays.

The main objective of this paper is to study and analyze different smart parking systems developed by researchers. This paper also identifies limitations in existing systems and proposes innovative solutions to improve performance.

LITERATURE REVIEW

Many researchers have proposed different smart parking solutions using advanced technologies.

Fahim et al. (2021) conducted a detailed review of smart parking systems and classified them into different categories based on sensing technologies and communication methods. The study concluded that IoT-based systems are widely used due to their flexibility and scalability.

Barriga et al. (2019) discussed the role of communication technologies such as LPWAN, Zigbee, Wi-Fi, and Bluetooth in smart parking systems. The study highlighted that communication efficiency is an important factor in system performance.

Kaur and Malhotra (2018) proposed an IoT-based smart parking system using sensors to detect vehicle presence. The system provides real-time data to users through a mobile application, making parking easier and faster.

Mathur et al. (2010) introduced the ParkNet system, which uses mobile sensing to detect parking availability. This system collects data while vehicles are moving and provides useful information about parking spaces.

Geng and Cassandras (2013) proposed a smart parking system based on optimal resource allocation. Their system focuses on improving parking efficiency using mathematical models.

Recent studies have also explored the use of Artificial Intelligence and Machine Learning for predicting parking availability. These systems use historical data to provide accurate predictions and improve decision-making.

Camera-based parking systems using image processing and deep learning techniques are also becoming popular. These systems provide high accuracy but require high computational resources.

From the literature, it is observed that while many systems are effective, they often focus on a single technology. There is a need for integrated systems that combine multiple technologies for better performance.

Methodology

This section presents the methodology adopted for the comprehensive literature review and the proposed smart parking management system. The methodology is based on the analysis of existing research works and the integration of advanced technologies to overcome their limitations.

Research Methodology in Literature

In most of the existing research, a systematic approach is followed to study smart parking systems. Researchers typically collect relevant journal papers, conference articles, and patents related to parking technologies. These studies are then analyzed and classified based on different parameters such as sensing techniques, communication technologies, and system architecture.

The literature shows that smart parking systems are generally evaluated based on performance metrics such as accuracy, cost, scalability, and user convenience. This structured approach helps in identifying the strengths and weaknesses of existing systems.

General Architecture of Smart Parking Systems

Based on the literature survey, a common architecture is identified, which consists of four main layers:

Sensing Layer

This layer includes sensors and cameras used to detect vehicle presence in parking slots. Ultrasonic sensors and image-based detection methods are commonly used.

Communication Layer

This layer is responsible for transmitting data from sensors to the processing unit. Technologies such as Wi-Fi, Zigbee, and LPWAN are used for communication.

Processing Layer

In this layer, the collected data is processed using cloud servers or local processing units such as Raspberry Pi. Data analysis and decision-making algorithms are implemented here.

Application Layer

This layer provides interaction with users through mobile applications or display systems. It shows parking availability and guides users.

Methodologies Used in Existing Systems

Different methodologies have been proposed in the literature, which are discussed below:

Sensor-Based Methodology

Sensor-based systems use ultrasonic or infrared sensors to detect parking occupancy. These systems are simple and cost-effective but may suffer from accuracy issues.

Camera-Based Methodology

Camera-based systems use image processing techniques to detect vehicles. These systems provide higher accuracy but require more computational resources.

IoT-Based Methodology

IoT-based systems connect multiple devices through the internet to provide real-time parking information. These systems are scalable but depend on network availability.

AI-Based Methodology

Artificial Intelligence is used in modern systems to predict parking availability based on historical data. This improves decision-making but increases system complexity.

ANPR-Based Methodology

Automatic Number Plate Recognition systems are used for vehicle identification and automated entry/exit management. These systems enhance automation and security.

Limitations of Existing Methodologies

Despite the advancements, existing methodologies have several limitations:

- Most systems rely on a single technology
- Limited integration of AI and IoT
- Lack of advanced security features
- Poor prediction capabilities
- Limited user-centric services

These limitations indicate the need for a more advanced and integrated system.

Proposed Methodology

To address the limitations identified in the literature, a hybrid methodology is proposed by integrating multiple technologies, as illustrated in the system architecture diagram.

Vehicle Detection Using YOLOv8

A deep learning-based object detection model (YOLOv8) is used to detect vehicles at the entry . This method provides high accuracy and real-time performance.

Number Plate Recognition Using OCR

Optical Character Recognition is used to extract the vehicle number from captured images. This enables automated identification of vehicles.

Face Recognition for Security

A face recognition module is integrated to identify authorized users. This enhances the security of the parking system.

Parking Slot Detection

Parking slots are monitored using sensors and camera-based techniques to determine occupancy status. This hybrid approach improves detection accuracy.

IoT-Based Communication

All devices are connected using IoT technology to enable real-time data transmission between sensors, processing units, and the cloud server.

AI-Based Prediction

Machine learning algorithms are used to analyse historical data and predict parking availability. This helps users in planning their parking.

User Interface and Guidance System

Users can access parking information through a mobile application or LED display. The system provides guidance to available parking slots.

Additional Features

The proposed system also includes advanced features such as:

Find My Car functionality

Smart parking guidance

Automated billing and exit system

Comparative Analysis

The proposed methodology is compared with existing systems as shown in Table 1.

Table 1: Comparison of Existing and Proposed Systems

Feature	Existing Systems	Proposed System
Technology Integration	Single	Multi (AI + IoT + Vision)
Security	Limited	Face Recognition
Automation	Partial	Full Automation
Prediction	Limited	AI-Based
User Features	Basic	Advanced (Find My Car, Guidance)

DESIGN

This section presents the system design of smart parking management systems based on the analysis of existing research work. The design combines sensing, communication, processing, and application layers along with mathematical modelling used in previous studies.

Research shows that modern smart parking systems are designed using IoT, sensors, and cloud computing to improve efficiency and reduce congestion. In addition, recent studies integrate Artificial Intelligence for prediction and optimization of parking spaces.

The system design of smart parking management is based on the analysis of existing research, which uses IoT, sensors, cloud computing, and artificial intelligence to improve parking efficiency.

Most systems follow a layered architecture including sensing, communication, processing, and application layers. The sensing layer detects vehicle presence, while the communication layer transfers data to the cloud. The processing layer analyzes the data, and the application layer provides information to users.

Parking occupancy is calculated using:

$$O = \frac{N_{occ}}{N_{total}}$$

Available slots are determined by:

$$N_{avail} = N_{total} - N_{occ}$$

Vehicle detection accuracy is measured using:

Io U = \frac {Area_{overlap}} {Area_{union}

Parking time and cost are calculated as:

$$T = T_{exit} - T_{entry}$$

$$C = T \times R$$

Recent studies also use AI models to predict parking availability:

$$P(t) = f(D_{hist}, t, \lambda)$$

Overall, the literature shows that integrating IoT, AI, and computer vision improves system performance, accuracy, and user experience compared to traditional parking system .

CONCLUSION

Smart parking management systems are essential for modern cities. This paper reviewed different technologies and approaches used in smart parking systems.

It is found that IoT, AI, and image processing play an important role in improving parking systems. However, there are still challenges like cost, privacy, and system integration.

Future systems should focus on advanced technologies like AI, cloud computing, and smart analytics to make parking systems more efficient and user-friendly.

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