

Development Of an Intelligent Smart Parking System Integrating Real-Time Monitoring, Dynamic Slot Allocation, And NoSQL Database for Smart City Applications

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Abstract—The Smart Parking System implementation which this paper describes uses real-time slot tracking through MongoDB NoSQL database to solve parking situation challenges. The system identifies available parking spaces which it immediately assigns to drivers while recording all vehicle movements through time-stamped data. The system operates through immediate vehicle tracking which enables it to identify available parking spaces and control space assignments with full movement documentation. People now take less than two minutes to find things after ten minutes of search time. The system. The search system AI reduced the average search time from ten minutes to less than two minutes. The improvement makes a substantial impact on operations. The system requires no human operation. The system shows a substantial enhancement of handling available space. The system allows cities to expand their infrastructure through IoT devices and machine learning systems and mobile application development whenever they reach their development milestones. Dynamic slot allocation MongoDB NoSQL database real-time parking management smart city smart parking system urban traffic congestion which operates in modern cities.

Index Terms—Smart Parking System, Real-Time Parking Management, Dynamic Slot Allocation, MongoDB NoSQL Database, Internet of Things (IoT), Vehicle Tracking, Parking Space Detection, Smart City, Urban Traffic Congestion, Machine Learning.

I. INTRODUCTION

Cities are expanding at a rapid pace. The speed of vehicle movement exceeds the rate at which cities develop. Urban areas worldwide face a hidden parking

problem which people choose to ignore because of their rapid growth. The problem exists because there is no available parking space. The existing systems from the past cannot handle this present-day demand because their limitations appear throughout various locations. Traffic obstructions cause vehicle operators to waste gasoline while their cars remain stationary. The increasing pollution levels lead to deteriorating air quality conditions. Researchers discovered that between 30% and 50% of urban traffic consists of vehicles which drive in circles without reaching any destination because they search for parking spaces. The situation brings about more than a simple trouble which needs to be solved. The present situation represents a complete breakdown of urban systems because they were developed according to outdated city planning methods. Old-fashioned parking systems operate without any direct visual guidance because they lack updated information about their parking spaces. The system lacks capacity to show available parking space information. The driver enters the parking area while hoping to find a parking space and then starts searching the area for one. The person keeps searching until they find the solution. The process wastes time because it leads to higher emissions from vehicles which already block the street while creating extreme dissatisfaction among drivers. The situation required an immediate solution which needed to happen without any delay. The need for advanced parking systems which operate with intelligent and interactive features became essential for cities after it reached the level of essential requirement. Smart Parking Systems offers its services to customers. The

combination of IoT and wireless communication and data analysis techniques has developed new possibilities for innovation during the past several years. Sensors establish communication links with networks. Networks transmit data to databases. The databases direct drivers to their designated parking locations. The system operates through standard engineering principles which have reached modern times because of their continued development through aging engineering methods.

II. LITERATURE SURVEY

Researchers have conducted extensive research on smart parking systems because they believe this technology can solve the urban parking challenges which currently exist between city streets and public spaces. The researchers applied three different methods to solve the problem which included sensor technology, strong communication systems, and algorithm development, and each method brought its own advantages to the project.

Enríquez et al. [1] provided a complete summary of current smart parking systems which included three detection methods: sensor-based systems, crowdsensing technology, and vision-based detection systems. The study showed that inefficient parking practices create both traffic congestion problems and environmental pollution, which most people do not understand.

Lin et al. [2] conducted an extensive review of smart parking systems which they organized into three sections: information collection, system deployment, and service dissemination. The researchers discovered that parking system operations depend entirely on two essential components which include real-time data acquisition and effective communication methods.

Intelligent Transportation Systems (ITS) contain intelligent parking systems which Faheem et al. [3] studied through their research of parking guidance systems and parking reservation systems and parking payment systems. The main point of their arguments states that a system requires automated operations and reliable performance to function as an actual aid instead of creating additional obstacles.

The study conducted by Paidi and his team members showed that all parking sensor technologies which included magnetometers and ultrasonic sensors and

machine vision were available for their examination. The research showed that parking efficiency increases through sensor systems which display available parking spaces to drivers who can then locate their vehicles without needing to search.

Channamallu and other researchers [5] studied how parking systems are using technology. The team demonstrated how modern smart parking solutions use Internet of Things technology together with Artificial Intelligence and wireless communication. The team showed that people tend to forget this important fact. Real-world system operation requires an organization to establish a data management solution which must provide both scalability and security features.

Shroud and other researchers [6] looked at the challenges and opportunities of parking sensor technology. The researchers proposed that machine vision combined with neural networks would provide better results and system performance than using individual methods. The use of one approach does not sufficiently address the problem.

Internet of Things has been extensively researched for parking systems development. Geng and Cassandras [7] proposed a system that uses the Internet of Things to monitor and manage parking in time which was a pretty smart idea, at the time. Ali and other researchers [8] built a parking system that uses wireless sensors to find and allocate parking spots efficiently.

Camera-based detection has also gotten some attention. Lin et al. [9] proposed a vision-based system that uses image processing to figure out parking occupancy. The system operates effectively under specific conditions although it struggles to handle changing light environments. The task presents greater difficulty than what it initially seems to be.

To cut down on infrastructure costs crowdsensing approaches have also been tried out. Mathur et al. [10] Used a sensing-based detection system that uses sensors mounted on vehicles to gather parking data as they move around. That is a solution.

Cloud-based management has naturally gotten a lot of attention because of how it scales. Zhang et al. [11] Developed a cloud-integrated parking system that could store and process real-time parking data without the usual bottlenecks. When you are dealing with data at that speed and volume cloud integration makes a difference.

Recent research is starting to look at machine learning for predicting availability before drivers even get there. Huang et al. [12] built a model which analyses historical parking data to forecast future parking slot availability. The concept appears obvious because it exists as one of those ideas which seemed clear from the beginning.

Researchers have conducted thorough research to study the economic aspects of the situation. Rowse [13] developed theoretical models which demonstrate how driver behavior connects with search time and pricing in parking facilities. The research provided essential foundation material for future demand-responsive methods to develop their programs.

Dhulipala [14] showed a sensor-based system which connects real-time monitoring to main control operations. The team achieved big improvements when they implemented automated detection which helped them find parking spaces faster while they searched. System-level thinking at this level represents the special method which brings effective change.

Idris et al. [15] performed a review of car park systems which categorized the systems according to their detection methods and communication protocols and guidance strategies. The survey revealed design factors which all developers of expandable smart parking systems must consider to build successful infrastructures.

Researchers have studied reservation-based parking systems because they work with vehicular ad hoc networks. Delot et al. [16] created a reservation protocol which allows vehicles to reserve parking spaces before their arrival. The method helps drivers find parking spaces faster while it enables better coordination among drivers who navigate through busy urban areas.

Polycarpou et al. [17] performed an evaluation of smart parking systems which operate in urban environments through testing both infrastructure-based systems and cooperative systems. The researchers discovered an authentic assessment of three essential factors which include system complexity and deployment expenses together with the actual performance advancements which can be obtained.

Evenepoel et al. [18] examined smart parking implementation costs together with their benefits. The

researchers evaluated different technologies to determine their practical applications but their findings reached a straightforward conclusion. The software-based systems which can grow according to needs provide investors with guaranteed returns. The performance of expensive hardware-dependent systems does not meet expectations.

The industry has made its own contribution to this area. Xerox Corporation [19] created advanced smart parking management systems for enterprises which combine sensor information with analytical tools and mobile platforms to serve large urban spaces. The company has developed engineering capabilities which make their work become essential for others to observe.

Shaheen et al. [20] conducted field experiments of smart parking management which they implemented in the San Francisco Bay Area. The actual results showed decreased cruising duration together with improved space management and pricing that adjusted to actual demand which directed customers to specific locations. The real-world tests provide greater persuasive power than the simulated results.

The large-scale testing of urban areas constitutes the next step. The SmartSantander project [21] established a complete Internet of Things system throughout the city which included parking sensors to demonstrate that parking systems can work within a comprehensive smart city system through actual implementation.

The city of Los Angeles launched LA Express Park [22] which introduced an immediate parking system throughout the entire city. The system used dynamic pricing together with real-time data on parking space availability to manage thousands of parking spaces throughout one of the most crowded urban centers in America. The system operated correctly. The deployment process for this system demonstrated how the concept operates at full operational capacity.

SFpark [23] implemented demand-based pricing for street parking and garage parking facilities in San Francisco. The system used occupancy information from sensors to update parking prices while directing drivers to vacant parking locations. The system achieved its goal by decreasing parking-related traffic congestion. The concept involves a straightforward approach which generates substantial outcomes. Urbiotica [24] developed wireless smart parking

sensors to monitor both outdoor parking facilities and street parking areas. The system provides low power consumption together with simple installation and dependable vacancy detection which enables cities to expand their operations without exceeding their financial limitations.

Libelium [25] developed a smart city sensor platform which enables multiple urban services and parking operations to function together. Their modular Internet of Things system architecture enables organizations to execute their operations through various deployment methods while establishing connections to cloud services.

III. PROPOSED SYSTEM

The Smart Parking System we are presenting needs to achieve actual operational efficiency together with its planned scalability. The system operates based upon three components which include current situation monitoring and automatic parking space distribution and NoSQL database systems that provide optimal data management. Every element holds significance because when you remove one element the system's stability starts to decline. The main objective establishes two objectives which require drivers to find parking spaces faster and ensure proper utilization of parking facilities. The system automatically tracks each vehicle entry and exit. The system maintains continuous parking status updates. The system operates without any delays. The system requires no human intervention to function.

The system operates through four essential functions which include (i) identifying which parking spaces are currently vacant and (ii) assigning those spaces to vehicles that arrive at the facility. The process requires multiple steps to connect different components. The system demonstrates a clear contrast with traditional parking systems which creates a highly visible distinction between both systems. The system requires less manual operation which leads to substantial operational efficiency improvements. The system achieves higher operational efficiency. The document-oriented database system we implemented provides our organization with adaptable data management capabilities which allow us to increase system capacity for handling expanding parking facilities.

IV. OBJECTIVES

The Smart Parking System aims to create a solution that functions effectively in the real world through its implementation of real-time parking management which handles parking space allocation and improves parking space usage. The project goes beyond being a prototype to deliver a complete functioning system.

The system plans to implement its objectives through two main components.

- 1)The system needs to develop a technology that will identify and track open parking spaces through continuous real-time monitoring without any time delays or estimation methods.
- 2)The system needs to create a dynamic slot allocation system which will distribute parking spaces to incoming vehicles throughout the day.
- 3)The solution should decrease both traffic congestion and fuel usage which occurs when vehicles drive around looking for parking spaces because this problem creates actual expenses.
- 4)The system will use a NoSQL database (MongoDB) to store and control all parking information which enables the system to maintain efficient and expandable data processing from its initial operation.
- 5)The system will execute all entry and exit operations through automated timestamp collection and record updates which require no human intervention.
- 6)The system design permits users to move through the system without needing to control their own movements.
- 7)The system architecture allows developers to build scalable systems which will support new IoT devices and mobile applications and intelligent prediction models without requiring system reconstruction.
- 8)The system will enhance parking efficiency through its ability to decrease average search times for parking spaces.

V. SYSTEM ARCHITECTURE

The system architecture consists of four main elements which include the Entry Module, Slot Management Module, Database Module, and Exit Module. Each of these elements performs its own function which enables the entire system to operate efficiently during

real-time parking operations. All components of the system interact with one another because no component exists as an independent unit.

The Entry Module handles the first interaction. The parking area module records vehicle number and entry time when a vehicle arrives at the parking area which then starts to search for open parking spaces.

Its fast. It has to be. Next, we will discuss the Slot Management Module. The system operates its primary function because it detects free parking spots which it uses to allocate to incoming vehicles while it oversees the complete parking area of the facility. The system provides status updates which occur in real time. The system provides updates which occur continuously throughout the day.

The Database Module functions as the main element which enables all system procedures to operate. The system uses MongoDB which functions as a NoSQL database to store all data including vehicle numbers and slot numbers and entry times and exit times and parking status information. The system maintains operational integrity because MongoDB provides a development process which allows data developers to implement needed data modifications. The system handles real-time updates because it operates without difficulties.

The Exit Module functions as the last element which completes the system operation. The module updates the database record when a vehicle departs from the facility which means it also designates the parking space as accessible to other vehicles while it records the time of departure. The system operates with complete efficiency because it performs all tasks without requiring any manual efforts from operators. The four modules create a complete system experience because their interactions show how different parts of the system work together. The system lets us watch what is happening in time. It also helps us use the parking slots in a way and manage the parking area properly.

The system is designed in a way that it can grow with us. We can add things, like IoT sensors and mobile applications and cloud services to the system without having to rebuild it from scratch. The system architecture is good because it supports growth of the parking management functions and the system itself.

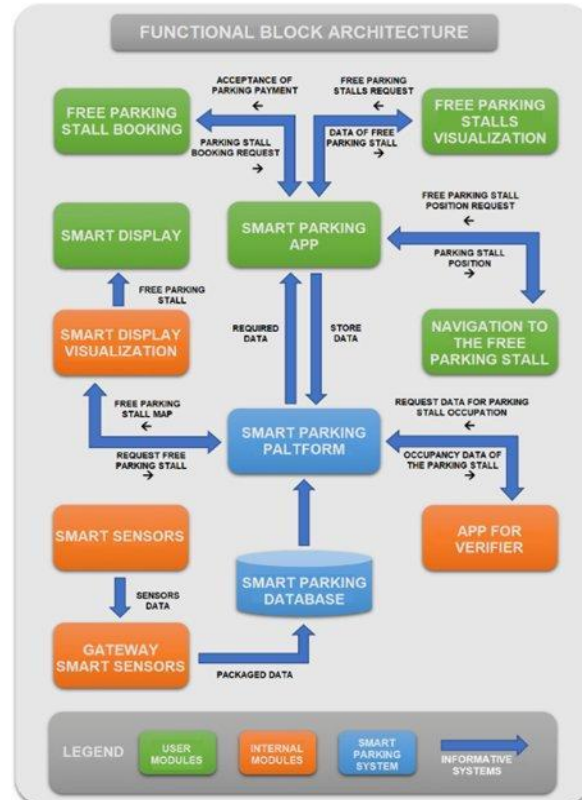


Fig. 1. Functional Block Architecture of the Smart Parking System

VI. PROPOSED METHODOLOGY

The way this system works is about how it moves from finding a parking spot to giving you a spot to managing the information using a NoSQL database every step of the way. This system is made up of parts that work together. It is very important to be accurate and to be able to handle a lot of people because you cannot afford to make mistakes when it comes to parking.

At the center of this system there is a database that keeps track of every single parking spot. Each spot has its information. Like the spot number if it is available the cars number, what time it came in and what time it left. This system is always. Updating this information and it reacts every time a car comes or goes.

When a car shows up the part of the system that handles arrivals gets to work away. It takes down the car's information. Like its number and what time, it came in. Then it checks the database to see what spots are available. Then the system decides which spot is

best for the car, based on things like which spot's closest and which one is next in line.

Once a spot is chosen the database is updated away. The spot is marked as taken and the cars information is stored. Then the system shows the person which spot's theirs so they know exactly where to go. This all happens quickly and easily so there is no confusion. The parked vehicle system operates its parking management functions because it continuously monitors which parking spaces remain occupied and which spaces remain vacant. The system uses this method to maintain current knowledge about parking space availability.

The system detects when the car departs from the parking space because it uses departure procedures to access vehicle details from the database. The system records the time of departure. The system then designates the parking space as vacant which permits entry to the next vehicle that arrives. The entire process operates without encountering any difficulties. The database system called MongoDB is very important here. The system excels at managing dynamic information because of its capacity to handle extensive data through its flexible capabilities. The system enables real-time data updates without encountering intricate data management challenges.

This system operates through an easy process which starts when a car arrives and the system assigns an available space to the car while it updates its records until the car departs and the parking spot becomes free. The system keeps improving its performance through successive operations which study how the system manages its tasks. The system requires additional time to locate parking spaces while it boosts space utilization and operates without system performance issues.

The current stage represents only the initial phase of the project. This system requires enhancements through special sensor technology which detects empty parking spaces and through computer programs that forecast parking space availability and through mobile applications that facilitate system access. MongoDB provides data management capabilities to parking management systems that operate similar to this parking system. The system monitors both parking spaces and vehicle movements. The system uses this information to create a simplified parking experience.

VII. TECHNOLOGY USED

The system uses contemporary software the system uses current database technologies which enable real-time performance to handle system growth while managing data efficiently. The system operates using three main components which work together as its fundamental operational system.

A. Programming Language

The core system uses a high-level programming language which allows Python or Java or Node.js to run based on the specific deployment requirements. The choice allows flexible development through its built-in database connectivity which supports real-time processing capabilities.

B. Database (MongoDB)

The system selects MongoDB as its database solution because it operates as a NoSQL document-oriented system which provides flexible parking data storage capabilities. The system tracks all vehicle activities from entry and exit processes to monitoring parking slot status. The system uses a schema system which allows flexible schema alterations without system disruptions while providing real-time update functionality that works effectively at large system capacities. The system needs MongoDB because it operates in an environment which requires constant updates.

C. Development Tools

Developers used Visual Studio Code or Eclipse as their preferred IDEs for both development and debugging purposes. The development process benefits from these tools because they provide code management and debugging support and plugin integration which prevents unnecessary difficulties during development

D. MongoDB Compass

The graphical interface of MongoDB Compass enables users to control and view the contents of the database.

The visual layer of the database system makes it much easier to work with because users can create collections and insert documents and monitor the parking data that is stored in the system.

E. Communication and Interface

The system currently offers two interface options which include web-based interfaces and console-based interfaces to show parking space availability and system operational status. The upcoming development of mobile applications will enable user interaction which represents a necessary progress point for the project.

F. System Environment

The development and testing process used standard computing environments which included database server and runtime support as testing environments. The system can operate from local systems while also supporting deployment to cloud platforms which provide improved access and additional scaling capabilities. Both paths work. The system achieves optimal performance through its ability to process real-time data and its capacity for expansion and system upgrades which require no substantial modifications. IoT integration, predictive analytics—those are not wishful additions. The architecture has been designed from the beginning to support those requirements.

VIII. RESULTS AND DISCUSSION

The system testing process evaluated operational performance through tests that simulated various operational scenarios. The assessment included three aspects which were parking efficiency and response time and data management. The main duty required tracking vehicle movements while using MongoDB to monitor current parking space availability. The system prohibits execution of this task.

The results show some strange results which we need to discuss. Drivers who search for parking spaces usually spend ten minutes looking for available spots. It requires them ten minutes to complete this task which they need to finish. The system has a design problem which creates actual problems with parking operations. The system continuously monitors parking spaces which enables people to find available spaces within two minutes. The parking system maintains continuous knowledge of vacant spaces because it inspects all parking facilities at all times. The parking system continuously monitors parking spaces to detect which spaces remain unoccupied by vehicles. The parking system requires repair because it currently

operates with multiple faults which affect its performance.

The system uses parking space through its continuous process of updating available parking spots. The database maintains information accuracy because it receives real-time updates. The system contains no outdated information while it prevents double bookings and it keeps track of which spots remain occupied and which spots remain available. MongoDB processes all system updates with its sufficient speed capacity. The system maintains its functionality during times of high vehicle traffic. The parking system operates together with MongoDB to maintain real-time information about parking spot availability.

The automation component represents a major development for the project. The system achieves strong efficiency improvements because it removes human control over slot allocation and status updates. Operational efficiency improves through the automated process. The system eliminates all possibilities of human errors which would damage the complete record system.

The Table I presents a comparison between the conventional parking system and the newly developed system.

TABLE I. PERFORMANCE COMPARISON

Parameter	Traditional System	Proposed System
Parking Search Time	~10 minutes	~2 minutes
Slot Allocation	Manual	Automatic
Data Management	Manual/Static	Real-time
Efficiency	Low	High
Scalability	Limited	High

The study results show that this system delivers vital improvements to parking management because it reduces time spent searching for parking spaces while boosting space utilization and its data handling abilities can adapt to current needs which require processing real-time information. The system only uses software-based vehicle tracking method for vehicle movement detection which limits its operational capabilities. The system needs IoT sensor

integration as its next development step because this technology will achieve complete automated detection capabilities.

A. Vehicle Detection and Classification

The system uses the YOLO algorithm to find and classify vehicles. The YOLO algorithm achieves excellent object detection performance because it analyzes complete images in a single analysis. The system produces output results because it utilizes deep learning technology to execute simultaneous object tracking tasks. The system operates optimally for applications which require precise timing.

The model finds things and shows them in Figure 2. The system can distinguish between two types of vehicles bicycles and motorcycles. The system establishes a unique score for each detected object which indicates the level of confidence that the system possesses. The system uses rectangular boxes to display both the positions and identities of all detected objects. The system handles bicycle detection with high certainty, assigning it a detection score of 0.92. The system handles motorcycle detection with high certainty, assigning it a detection score of 0.85. The system identifies all objects which it detects as either vehicles or non-vehicles. The Vehicle Detection and Classification system demonstrates excellent vehicle detection capabilities which the YOLO algorithm effectively enhances.



Fig. 2. YOLO-based Vehicle Detection and Classification

B. Number Plate Detection and Recognition

The system proceeds to number plate detection after it successfully identifies a motor vehicle. The visual representation in Fig. 3 shows the system detected the vehicle through a blue bounding box which marks the scooter as confirmed detection. The system uses a yellow bounding box to define the area which contains the number plate while everything else on the vehicle remains excluded from that boundary. Optical

Character Recognition (OCR) extracts alphanumeric characters from the plate through its scanning process. The registration number which depends on image clarity gets transformed into machine-readable text. The system transmits the data directly into the database system which supports parking management and vehicle tracking and automated security and other required applications.

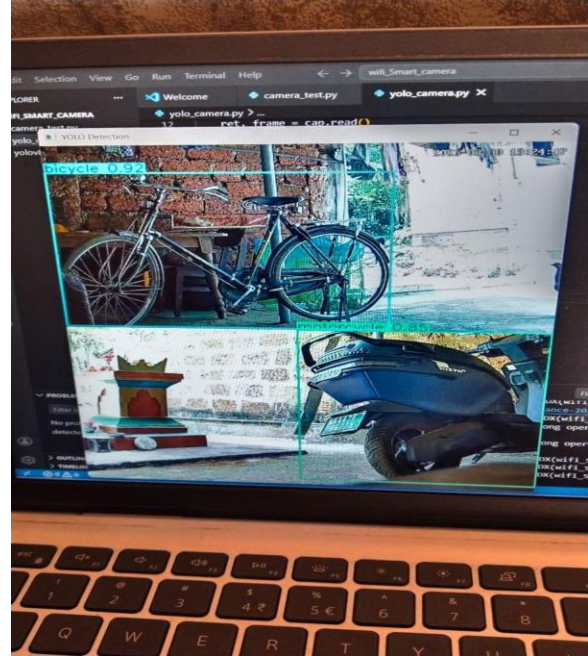


Fig. 3. Number Plate Detection and OCR Recognition

Solving a number of common parking problems, the Smart Parking System demonstrates that it is truly scalable and extremely effective in solving the kind of contemporary urban parking issues being faced by cities today.

IX. CONCLUSION

The street parking system in urban areas has become completely unmanageable because of its current faults. This document described our process for addressing a portion of the existing disarray. The Smart Parking System we created combines two technologies to solve an essential urban mobility challenge. The system provides dynamic slot allocation through automated records which eliminate all manual processes required for determining available slots.

The system operates correctly. The outcome showed distinct results. The researchers achieved a major

search time reduction which decreased from ten minutes to less than two minutes. The area used for parking spaces showed substantial improvement. The system reached almost complete automation because it required almost no human input. The system design leads to improved parking results because it creates a more user-friendly experience for drivers.

MongoDB existed as the ideal database solution for our needs. The system provides flexible options which enable quick data access. The system handles continuous data changes that occur throughout parking operations while processing large volumes of data. The system design used modular components to create a system which can expand its capabilities through upcoming software expansions. The system permits additional features which allow new systems to connect without interrupting existing operations.

The future development of the system will proceed to multiple different destinations. The system needs IoT sensors to create an automatic system which detects available parking spaces. Drivers will use mobile applications to find parking spaces without any active searching process. Machine learning will enable the system to show available parking spaces before drivers reach the parking area. The complete system design already demonstrates these theoretical components which the system will use to move toward its next stages of development.

The Smart Parking System demonstrates effective functionality because it operates successfully. The system delivers useful results.

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