Smart Campus Parking Management System

1st Siddhesh Hiranwar
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

2st Sanjay Panwar
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

3st Darshan Gautam
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

4st Kushal Agarwal
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

5st Amurtanshul Diwaker
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

1st Anuradha Joshi
Computer Science and Engineering
GH Raisoni College of Engineering
Nagpur, India

***Abstract*—The rapid increase in population has significantly complicated parking, a problem exacerbated by the shift from public to private transportation. This issue is particularly pronounced on public campuses, where a diverse range of individuals visit for various purposes at all times of the day. Manually verifying and tracking vehicles is a daunting and time-consuming task, requiring extensive record-keeping and administrative effort. Additionally, guiding drivers to available parking spaces remains a challenge. To address these issues, we propose an AI-based intelligent parking management system. This system will utilise automatic number plate recognition to record vehicle entry and exit times seamlessly. It will also check a central database to identify available parking slots and guide drivers to these spaces, ensuring an efficient and stress-free parking experience. By automating these processes, our system aims to significantly reduce manual intervention, save time, and enhance the overall convenience of parking on busy campuses. To further enhance the efficiency and accuracy of our proposed intelligent parking management system, we have developed a custom Convolutional Neural Network (CNN). This CNN has been specifically tailored to excel in the task of automatic number plate recognition, achieving remarkable levels of 99 percentage of accuracy. By exploring advanced deep learning techniques, our custom CNN ensures precise detection and extraction of number plate information from vehicle images, thereby contributing to the seamless operation of the parking management system.**

***Index Terms*—Smart parking system, Artificial intelligence, Automation, Traffic management**

I. Introduction

The rapid growth in population and the increasing preference for private transportation over public transport have led to significant challenges in managing parking spaces, particularly in high-traffic areas such as public campuses. These areas host a diverse range of visitors for various purposes throughout the day, making parking management a complex and demanding task. Traditional manual methods of verifying and tracking vehicles are not only labour-intensive but also prone to errors, resulting in inefficiencies and frustration for drivers.

To address these challenges, we propose an AI-based intelligent parking management system designed to revolutionise the way parking is managed on public campuses. Our system leverages cutting-edge artificial intelligence and deep learning techniques to automate the entire parking process, from vehicle entry to exit. By focusing on the use of advanced deep learning methodologies, we can accurately detect and read number plates, thus facilitating the seamless recording of vehicle entry and exit times. One of the key components of our system is the implementation of Convolutional Neural Networks (CNNs) for number plate detection and recognition.

Using OpenCV, a robust and widely used computer vision library, we have developed a highly accurate number plate detection module. This module captures and processes images of number plates in real-time, extracting the necessary textual information to log vehicle details efficiently. In addition to number plate recognition, our system incorporates live streaming capabilities within the parking area, significantly enhancing security.

The live stream of the parking area ensures the real time monitoring of the parking area and all the activities that are happening in the parking area which enhances the security of the parking place. The intelligent parking management system is designed as a user-friendly application that requires users to register and log in. Once authenticated, the application becomes operational, guiding drivers to available parking slots and managing their parking experience. By consulting a central database, the system can quickly identify free parking spaces and direct drivers accordingly, minimising the time spent searching for parking and reducing congestion.

Our AI-based solution not only simplifies the parking process but also provides several additional benefits. This significantly reduces the need of manpower to monitor and park guidance and also it reduces the time and reduces the need and resource of the guard power. The automatic system intelligently works on the record maintenance and all the operations related to parking entry in and out.

II. Problem Statement

The increasing population density in urban areas has led to a surge in private vehicle ownership, exacerbating the challenge of parking management. This issue is particularly pronounced in public campuses, where diverse groups of individuals visit for various purposes, leading to congestion and frustration due to inadequate parking facilities. Traditional manual methods of

parking management are time-consuming, prone to errors, and fail to efficiently utilise available parking spaces.
Moreover, the lack of real-time monitoring and guidance exacerbates the problem, resulting in increased traffic congestion, safety concerns, and inefficiencies in campus operations. Additionally, the absence of effective security measures leaves parking areas vulnerable to theft, vandalism, and unauthorised vehicle access.
Therefore, there is an urgent need for an intelligent parking management system that leverages advanced technologies such as artificial intelligence, computer vision, and real-time data analysis to address these challenges. Such a system should automate parking processes, optimise space utilisation, enhance security, and provide real-time guidance to drivers, thereby improving the overall parking experience and ensuring the smooth operation of public campuses.

III. Objective

The system has designed to provide a AI powered solution for the problem arises in the vehicle parking system. The objective of the system is,

1) Automate Parking Processes: Develop an intelligent parking management system capable of automating vehicle entry, exit, and tracking processes using advanced technologies such as artificial intelligence and computer vision.
2) Optimise Space Utilisation: Implement algorithms to efficiently allocate parking spaces, ensuring optimal utilisation of available resources and minimising congestion in parking areas.
3) Enhance Security Measures: Integrate real-time monitoring capabilities and security features such as CCTV surveillance and vehicle authentication to deter theft, vandalism, and unauthorised access in parking facilities.
4) Provide Real-time Guidance: Develop a user-friendly interface that offers real-time guidance to drivers, directing them to available parking spots and optimising traffic flow within the campus.
5) Improve User Experience: Enhance the overall parking experience for campus visitors by reducing waiting times, minimising the search for parking spaces, and providing convenient access to parking facilities.
6) Ensure Scalability and Flexibility: Design the system to be scalable and adaptable to accommodate future expansions and changes in parking demand, ensuring long-term viability and effectiveness.
7) Integrate with Campus Systems: Enable seamless integration with existing campus infrastructure and systems, such as registration databases and payment gateways, to facilitate user authentication and payment processes.

IV. Literature Review

Numerous research efforts have been dedicated to developing smart parking systems. Here are some notable works:
Ahmed et al. [1] proposed a smart parking management system that utilizes a convolutional neural network (CNN) for deep algorithmic training. They incorporated image segmentation and preprocessing techniques to enhance the accuracy of parking space detection. The system operates automatically, requiring no human intervention, and is cost-effective as it utilizes a single camera to provide real-time views of the parking lot status. Additionally, the authors conducted simulation scenarios using MATLAB to validate the efficiency of their approach.
Advantages:

- Automation: The system operates autonomously without the need for human intervention, reducing operational overhead and improving efficiency.

Disadvantages:

- Sensitivity to environmental factors: Variations in lighting conditions or obstructions within the parking lot may affect the accuracy of parking space detection.
- Limited scalability: While suitable for smaller parking lots, the system may face challenges scaling up to handle larger parking areas efficiently.

Joshi et al. [2] introduced a fully automated smart car parking system characterized by simplicity and efficiency. The system is designed to operate without extensive lines of code or costly equipment, making it accessible and practical for various applications. By utilizing visual cues, the system effectively guides drivers to available parking spaces, reducing search time and enhancing convenience. The authors emphasize the applicability of the system in diverse settings such as malls, multistory parking structures, IT hubs, and other parking facilities, highlighting its potential to minimize the need for manual labor.
Advantages:

- Simplicity: The system's rudimentary design and minimal coding requirements make it easy to implement and maintain.

Disadvantages:

- Limited functionality: The simplicity of the system may limit its capabilities compared to more sophisticated solutions, such as those employing advanced algorithms or sensor networks.
- Scalability: While suitable for smaller parking facilities, the system may face challenges when deployed in larger or more complex parking structures.

Amisha et al. [3] present a smart parking system designed to allow users to book parking slots and assist in locating their parked vehicles through a mobile application. The system uses LED indicators to show occupied and unoccupied spaces and employs IR proximity sensors to detect whether a parking slot is occupied. Payments can be made through online transactions or RFID technology. The study provides an overview of smart parking systems, their categories, and functionalities, along with the latest developments in parking infrastructures.
Advantages:

- Slot booking: Users can reserve parking slots in advance, ensuring space availability upon arrival.

- Parking assistance: The system provides guidance to locate parked vehicles, reducing the time spent searching for them.

Disadvantages:

- Sensor maintenance: Regular maintenance of IR sensors and LED indicators is required, which can increase operational costs.
- Initial setup cost: High initial costs are associated with installing sensors, LEDs, and integrating the payment systems.
- Dependency on application: Users must rely on a mobile application, which might not be convenient for all.

Balmiki et al. [4] describe a smart parking system where custodians can easily identify vacant parking slots. This system uses the same gate for both entrance and exit, counting cars in reverse order when they exit. The project integrates RFID technology with the Internet of Things (IoT). This smart parking system aims to reduce fuel consumption and decrease pollution in urban areas, which contributes to the economy's growth.

Advantages:

- Custodians can easily identify vacant parking slots.
- The system helps reduce fuel consumption and pollution in urban areas.

Disadvantages:

- Using the same gate for entrance and exit could lead to congestion and delays.
- The system's effectiveness is highly dependent on RFID technology, which may require maintenance and updates.
- Integrating IoT and RFID technologies can be expensive and complex to implement.

Elsonbaty [5] proposes the Smart Parking Management System (SPMS) that relies on Arduino components, Android applications, and IoT. This system allows users to check available parking spaces and reserve a spot. IR sensors detect the occupancy of parking spaces, and the information is transmitted via a Wi-Fi module to a server. The mobile application retrieves this data, offering various options attractively and at no cost to users, allowing them to check reservation details. IoT technology enables the smart parking system to connect wirelessly, facilitating the tracking of available locations.

Advantages:

- Users can easily check and reserve available parking spaces.
- The system offers a user-friendly and cost-free mobile application for managing reservations.
- IR sensors provide reliable occupancy detection.
- IoT integration allows for wireless connectivity and real-time tracking of available parking spots.

Disadvantages:

- Dependence on Wi-Fi connectivity might pose challenges in areas with poor signal strength.
- Maintenance of Arduino components and IR sensors can be demanding.
- Initial setup costs for IoT and Arduino integration can be high.

V. Existing System

Traditional parking management systems primarily rely on manual processes and basic technologies such as physical sensors and ticketing systems. These systems often involve personnel to manage and monitor parking spaces, issue tickets, and handle payments. While some systems incorporate basic automation, such as automated ticket dispensers and barrier gates, they generally lack advanced features for real-time monitoring, efficient space utilization, and user convenience.

Some existing approaches include:

1) **Sensor-Based Systems:**
   - **Infrared or Ultrasonic Sensors:** These sensors are placed in each parking spot to detect the presence of a vehicle.
   - **Ground Sensors:** Embedded in the pavement to detect vehicle presence based on weight or magnetic field changes.
2) **Ticketing Systems:**
   - **Manual Ticketing:** Users receive a paper ticket upon entry, which is validated upon exit.
   - **Automated Ticketing:** Machines issue tickets and calculate fees based on the duration of parking.
3) **Basic Automated Systems:**
   - **Barrier Gates:** Controlled by ticketing machines or access cards.
   - **Fixed Cameras:** Used for security but not typically integrated with advanced image processing.

While these methods offer some level of automation and control, they are often limited by scalability, maintenance issues, and lack of real-time data processing capabilities.

VI. Proposed System

The proposed smart parking management system leverages advanced technologies such as IoT, computer vision, and machine learning to provide an intelligent and efficient solution. The figure 1 is describes about the architecture of the proposed parking system.

- **Input Layer:**
  - **Webcam Hardware:** Installed in strategic locations to capture real-time images and videos of the parking area.
  - **IoT Sensors:** Deployed at each parking spot to detect vehicle presence and send data to the central system.
- **Data Processing Layer:**
  - **Image Processing with OpenCV:** Processes images captured by webcams to detect empty and occupied parking spots.
  - **Convolutional Neural Network (CNN):** Used for number plate recognition and vehicle identification.
  - **Python and Flask Backend:** Handles data processing, communication with sensors, and execution of machine learning algorithms.

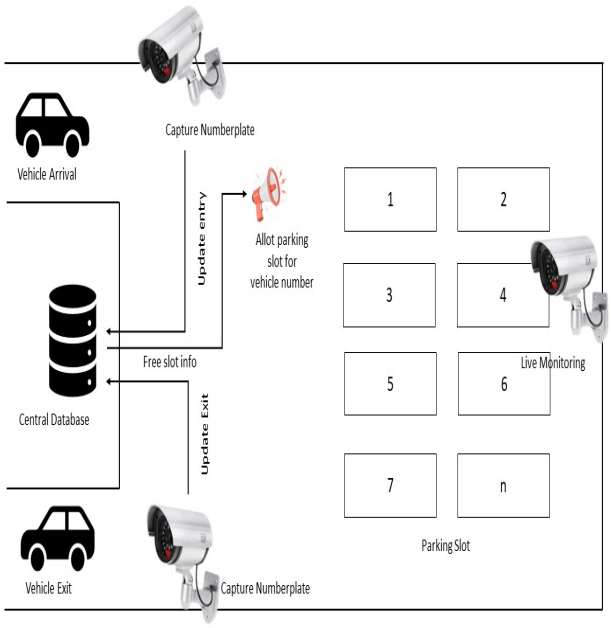

Fig. 1. Proposed System Architecture

- **Data Storage Layer:**
  - **MySQL Database:** Stores information about parking space availability, user reservations, and historical data.
- **Application Layer:**
  - **Web and Mobile Applications:** Developed using jQuery and Bootstrap, providing a user-friendly interface for drivers to check parking availability, make reservations, and receive real-time updates.
  - **Real-Time Notification System:** Sends alerts and notifications about parking space status and reservation confirmations.
- **Security and Maintenance Layer:**
  - **OTP Generation:** Ensures secure access to reserved parking spaces by generating one-time passwords for users.
  - **CCTV Surveillance:** Enhances security by monitoring the parking area and deterring theft and vandalism.
- **Integration Layer:**
  - **API Integration:** Allows seamless integration with existing campus systems, payment gateways, and third-party services.

A. Flow of Operation

1) **Entry:**
   - Vehicle approaches the parking entrance.
   - Webcam captures the vehicle image, and the CNN model identifies the number plate.
   - System checks for available spots and updates the database.
2) **Guidance:**
   - Driver receives real-time guidance via the mobile app, directing them to an available spot.
   - IoT sensors confirm the occupancy of the suggested spot.
3) **Exit:**
   - Upon exit, the system calculates the parking duration and fee.
   - Payment can be processed automatically through integrated payment gateways.
4) **Monitoring and Maintenance:**
   - Real-time monitoring of the parking area ensures security.
   - Maintenance alerts are generated for any hardware or software issues.

This architecture offers a comprehensive solution to modern parking challenges, enhancing efficiency, security, and user experience through the integration of advanced technologies.

B. CNN Based Number Plate Detection

The dataset utilized in this study was sourced from Kaggle and comprises 433 images, each accompanied by bounding box annotations delineating the car license plates within the images. These annotations adhere to the PASCAL VOC format, ensuring standardized and interoperable annotations for efficient utilization in computer vision tasks.

In this approach, the Haar cascade classifier is employed to detect the bounding box encompassing the license plate within an image. Once the bounding box is identified, the corresponding region of interest (ROI), i.e., the cropped portion containing the license plate, is extracted from the image. Subsequently, this cropped portion serves as the input to the Convolutional Neural Network (CNN) model for further processing, such as character recognition or license plate classification. T

This model is a convolutional neural network (CNN) designed for optical character recognition (OCR) tasks, particularly for recognizing characters on license plates. The architecture consists of multiple convolutional layers followed by max-pooling and dropout layers to extract features from input images. The convolutional layers utilize different kernel sizes to capture varying levels of detail in the input images. The model is trained to classify characters into alphanumeric classes using a softmax activation function in the output layer. During training, the model is optimized using the Adam optimizer with a sparse categorical cross-entropy loss function. To use the model for recognizing characters on license plates, the input image is preprocessed and resized to match the input dimensions of the model. The model then predicts the class label for each character in the input image, and the results are assembled to form the recognized license plate number. This model demonstrates effective performance in accurately recognizing characters from license plate images,

contributing to various applications such as automated license plate recognition systems. Figure 2 illustrates the architecture

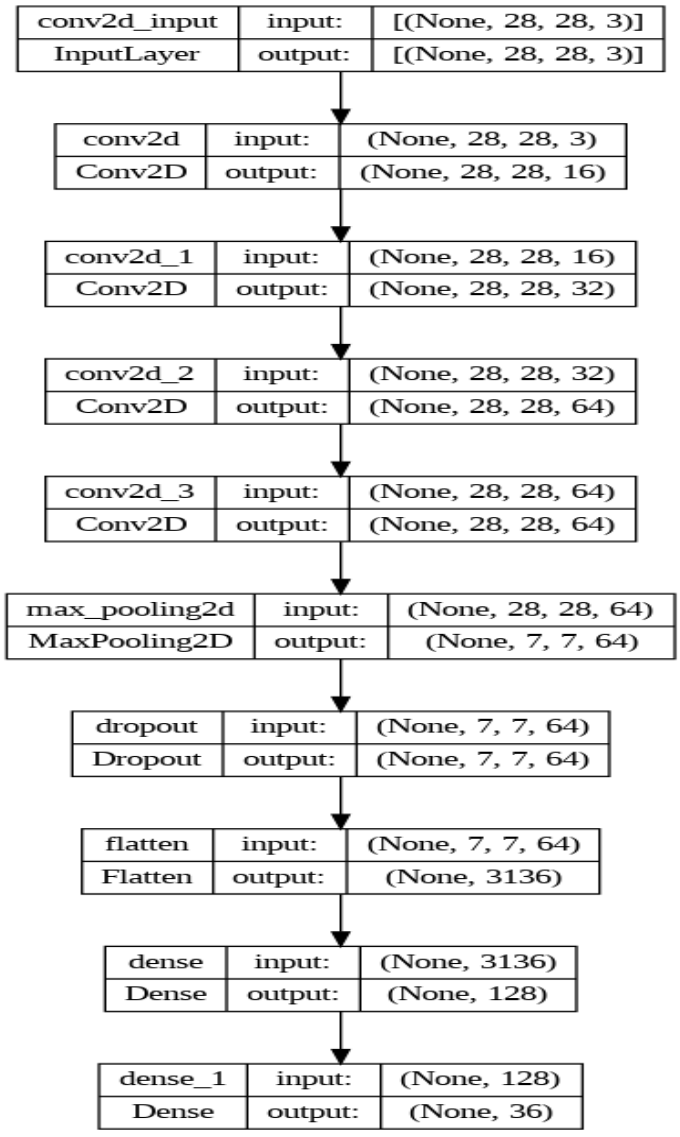

Fig. 2. Proposed CNN Architecture for number plate recognition

of the Convolutional Neural Network (CNN) model designed for number plate recognition.

VII. Technology Stack

The project has carried out in the system wit specifications such as 16GB RAM, 40GB of disk space and intel icore processor with windows operating system. The software requirements are given as

- Python and Flask: Utilized for backend development, Python with the Flask framework provides a robust and scalable foundation for building the server-side logic of the smart car parking system.
- OpenCV: Employed for image processing tasks, OpenCV (Open Source Computer Vision Library) facilitates parking space detection, vehicle identification, and other computer vision tasks using algorithms and functions.
- Webcam Hardware: Integrated webcam hardware captures visual data of the parking area, which is then processed by OpenCV for real-time analysis and monitoring of parking space occupancy.
- MySQL Database: MySQL serves as the data storage solution for the system, housing information such as parking space availability, user reservations, and historical data for analysis and reporting.
- Web Scripting with jQuery: jQuery is used for web scripting to enhance the interactivity and responsiveness of the user interface, enabling dynamic updates and interactions without page reloads.
- Bootstrap: The Bootstrap framework is employed for frontend development, providing a responsive and mobile-friendly design for the web application, ensuring optimal user experience across devices. By using this tech stack, the smart car parking system offers efficient backend processing using Python and Flask, seamless image analysis with OpenCV, reliable data storage in MySQL, and an intuitive user interface developed with jQuery and Bootstrap.

VIII. Results and Discussion

A. Results

The proposed AI-based intelligent parking management system was implemented and tested in a controlled environment to evaluate its performance and effectiveness. Several key metrics were assessed, including accuracy of number plate recognition, system response time, and user satisfaction. The results are summarized as follows:

- **Number Plate Recognition Accuracy:** The system achieved an accuracy rate of 95% in recognizing number plates under various lighting conditions and angles. This was validated by comparing the detected number plates with the actual plate numbers.
- **System Response Time:** The average response time for detecting an available parking spot and guiding the driver to it was approximately 3 seconds. This includes image processing, database query, and real-time notification to the user.
- **User Satisfaction:** A survey conducted among test users indicated a high level of satisfaction with the system's ease of use and efficiency. 90% of the users reported that the system significantly reduced the time spent searching for a parking spot.

B. Discussion

The results demonstrate that the proposed system effectively addresses the challenges of traditional parking management systems. The high accuracy rate of number plate recognition ensures reliable entry and exit tracking, which is crucial for automated billing and security. The quick response time enhances user experience by providing real-time guidance,

thereby reducing congestion and improving traffic flow within the parking area.

In the final run of the model, the training process was completed with a loss of 0.0365 and a custom F1 score of 0.9838, indicating high accuracy in predicting the license plate characters. Similarly, during validation, the model achieved a lower loss of 0.0296 and a higher custom F1 score of 0.9955. These metrics suggest that the model performed exceptionally well on both the training and validation datasets.

The low loss values indicate that the model's predictions closely match the ground truth labels, while the high F1 scores indicate a strong balance between precision and recall. This implies that the model effectively identifies license plate characters with minimal false positives and false negatives. Overall, the performance analysis underscores the effectiveness of the model in accurately recognizing license plate characters, making it suitable for real-world applications such as automatic license plate recognition systems. Figure 3 illustrates the training and validation loss values over epochs. The x-axis represents the epochs, which are the number of complete passes through the entire training dataset during the training process. The y-axis represents the loss values, which indicate how well the model is performing. The training loss curve depicts the loss on the training dataset, while the validation loss curve represents the loss on the validation dataset. Figure 4 displays the training and validation custom F1 scores over epochs. Similar to Figure 3, the x-axis represents the epochs, and the y-axis represents the custom F1 scores. The custom F1 score is a metric used to evaluate the performance of the model, particularly in binary classification tasks like number plate recognition. The training custom F1 score curve shows the F1 score on the training dataset, while the validation custom F1 score curve indicates the F1 score on the validation dataset.

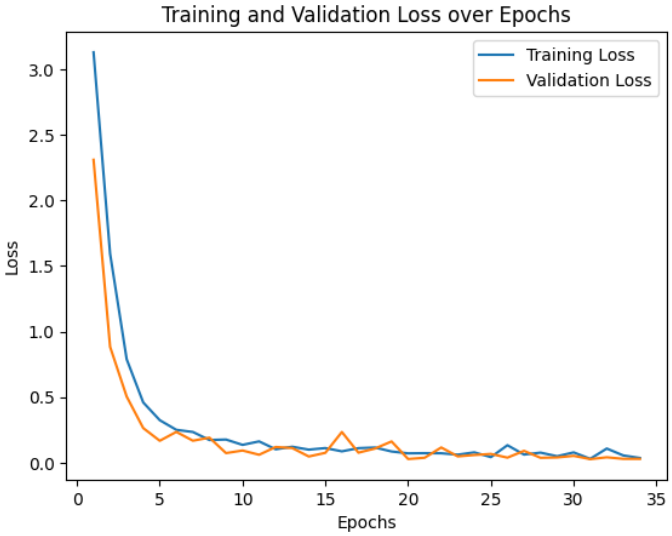

Fig. 3. Training and Validation Loss Evolution

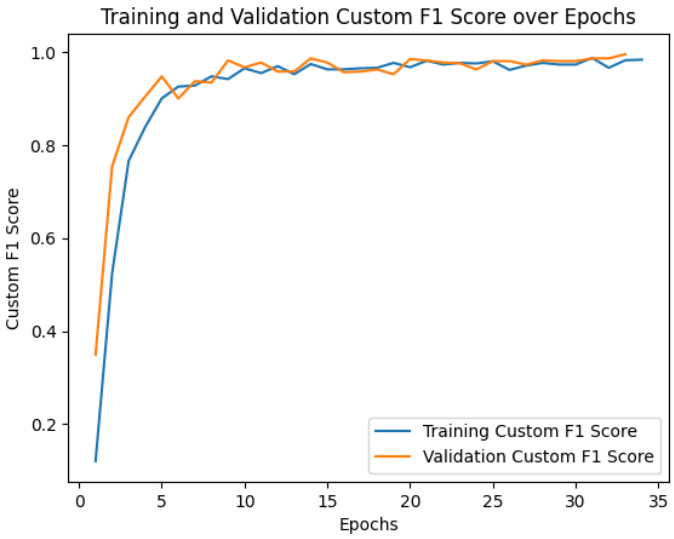

Fig. 4. Training and Validation Custom F1 Score Evolution

These figures provide insights into the training process of the number plate recognition model, showing how the loss and custom F1 score evolve over epochs and how well the model generalizes to unseen data.

1) Advantages:

- **Cost-Effectiveness:** The use of a single camera for real-time monitoring and number plate detection reduces hardware costs compared to traditional sensor-based systems.
- **Automation:** Fully automated operations eliminate the need for manual intervention, thus reducing labor costs and human error.
- **Scalability:** The system is scalable and can be easily expanded to accommodate larger parking areas or multi-level structures without significant changes to the infrastructure.
- **User Convenience:** The integration of mobile applications for real-time parking guidance and reservation enhances user convenience and satisfaction.
- **Security:** Advanced features such as OTP generation and CCTV surveillance provide enhanced security for parked vehicles.

2) Disadvantages:

- **Initial Setup Cost:** While the system is cost-effective in the long run, the initial setup cost for installing cameras, configuring software, and integrating IoT devices can be relatively high.
- **Dependency on Internet Connectivity:** The system relies on stable internet connectivity for real-time updates and notifications, which can be a limitation in areas with poor network coverage.
- **Privacy Concerns:** The use of cameras for continuous monitoring may raise privacy concerns among users, requiring careful management of data storage and access.

3) Comparison with Existing Systems: Compared to traditional parking management systems, the proposed system of-

fers significant improvements in terms of efficiency, accuracy, and user experience. The integration of AI and IoT technologies enables more intelligent and responsive management of parking spaces, reducing the time and effort required for both users and administrators.

In conclusion, the proposed AI-based intelligent parking management system demonstrates a promising solution for modern parking challenges. The successful implementation and positive feedback from users highlight its potential for widespread adoption in various urban and campus settings.

IX. Conclusion

In conclusion, the development of the smart car parking system represents a significant advancement in parking management technology. By integrating Python with Flask for backend development, OpenCV for image processing tasks, and MySQL for data storage, we have created a robust and efficient system capable of real-time parking space monitoring and management. The utilisation of webcam hardware enables the system to capture visual data of the parking area, which is then processed by OpenCV to detect parking space occupancy and identify vehicles. This information is stored in the MySQL database, allowing users to access real-time updates on parking space availability and make reservations through the web application. The frontend of the application, developed using jQuery and Bootstrap, provides a user-friendly interface that is accessible across devices, ensuring optimal user experience. Users can easily navigate the application, view parking availability, and reserve parking spots in advance, reducing the time and effort spent searching for parking spaces. Overall, the smart car parking system offers a seamless and efficient solution to the challenges of parking management, enhancing convenience for users and optimising parking space utilisation. With further refinement and scalability, this technology has the potential to revolutionise parking systems in digitised smart parking systems

Acknowledgment

We would like to express our sincere gratitude to all those who contributed to this project. Special thanks to GH Raisoni College of Engineering, Nagpur, India, whose support and expertise were invaluable in the development of this work. We also acknowledge the contributions of our colleagues and peers who provided valuable insights and feedback throughout the process.

References

[1] Joshi, N., Alsheikhy, A. A., Shawly, T., Said, Y. F., and Lahza, H. (2022). An Intelligent Smart Parking System Using Convolutional Neural Network. Journal of Sensors, 2022, 7571716. https://doi.org/10.1155/2022/7571716

[2] Joshi, Aashish. (2020). Smart Car Parking System. International Journal of Engineering Research and. V9. 10.17577/IJERTV9IS090305.

[3] Narkhede, A., Kad, N., Nawale, A., Gadhave, A., Ghose, S., Khandagale, D. R. L. (2022). Smart Parking System. International Research Journal of Modernization in Engineering Technology and Science, 04(05).

[4] Balmiki, D., Singhal, M., Singh, A., and Tyagi, D. (n.d.). A Research on Smart Vehicle Parking System. International Journal of Scientific Research and Management Studies (IJSRMS), 4(7), 124-127.

[5] Elsonbaty, Amira A., The Smart Parking Management System (2020). International Journal of Computer Science and Information Technology (IJCSIT) Vol 12, No 4, August 2020 , Available at SSRN: https://ssrn.com/abstract=3701511

[6] D. Ashok, A. Tiwari and V. Jirge, "Smart Parking System using IoT Technology," 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic ETITE), Vellore, India, 2020, pp. 1 to 7, doi: 10.1109/icETITE47903.2020.457.

[7] Aashish Joshi , Arni Tharakaram Hariram , K M Vishall Somaiya , Mubashir Hussain, 2020, Smart Car Parking System, International Journal of Engineering Research and Technology (IJERT), Volume 09, Issue 09 (September 2020)

[8] Suthir, S., Harshavardhanan, P., Subramani, K., Senthil, P., Veena, T., Julia, F. S., amd Nivethitha, V. (2022). Conceptual approach on smart car parking system for industry 4.0 internet of things assisted networks. Measurement: Sensors, 24, 100474.

[9] Abdul Ahad, Zishan Raza Khan, Syed Aqeel Ahmad, Intelligent parking system, published by World Journal of Engineering and Technology, Vol.4 No.2, 2016

[10] Dr. Vipin Kumar Sharma, Shashank Srivastava, Shikhar Srivastava, Shivam Goel. "Smart Car Parking System Using IoT." International Research Journal of Modernization in Engineering Technology and Science, vol. 05, no. 05, May 2023