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PARK VISION: INTELLIGENT PARKING MANAGEMENT SYSTEM

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Abstract

Over the past several years, there has been an increase in the number of automobiles in use. Larger parking lots are therefore clearly needed. The current standard techniques for identifying if a slot is occupied in smart car parking lots are no longer appropriate as they require a large number of costly sensors and the region that required observation growing. The purpose of this study is to determine, update, and display the current number of open parking spaces in the parking lot using an efficient, quick, and accurate method. A camera's worth of video was employed as the input medium, and the object identification technique for image processing was Yolov5. By comparing the independently discovered locations of parking lots and parked cars, available parking spots were assessed. The dataset utilized to train and assess the model was the PKLot database. The photographs included in the dataset that corresponded to various weather conditions were used to assess the performance of the suggested model. The model's performance was 90.03% on average. Bright days showed the best performance, and rainy days produced the lowest.

Keywords: Convolutional Neural Network, Computation of Images, Shortest Path Method, Smart Parking System, and Parking Spot Recognition.

1. INTRODUCTION

The utilization of vehicles has surged alongside the increasing urban population and enhanced living standards. According to statistics released by the Department of Motor Traffic in India spanning from[1-8], there has been a consistent rise in vehicle numbers. In metropolitan areas, significant concerns include traffic congestion and the difficulty in locating free parking spaces. Consequently, the demand for monitoring expansive parking areas has escalated, prompting the expansion of parking facilities. However, a majority of current parking facilities operate inefficiently. Present-day parking lots often fail to meet drivers' expectations, leading to extended circling times on busy days as vehicles search for available spots. Despite the abundance of parking lots, drivers frequently struggle to find suitable spaces due to improper management. This challenge not only contributes to traffic jams and increased carbon dioxide emissions but also results in energy wastage, accidents, and heightened stress levels among drivers. The primary issue encountered in parking lots is the inefficient use of time spent searching for vacant spots, adversely affecting resource efficiency[9] and public health[10].On average, drivers spend approximately ten minutes searching for parking in urban areas. Intelligent parking solutions have been developed to address these challenges, employing various detection techniques utilizing magnetic[11], ultrasonic [12, 13], RFID [14, 15] Internet of Things (IoT) [16-17], and geomagnetic sensors to ascertain parking space occupancy. The Canny

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Edge Detection method stands out as one of the most widely adopted algorithms in this field. However, current solutions are hampered by their high cost, poor performance in adverse weather conditions, lack of precision, and constraints in managing small parking spaces. There remains a research gap in identifying quick, cost-effective methods suitable for wide-area monitoring. Park Vision represents an innovative approach to enhancing parking efficiency and convenience in urban settings. This intelligent parking management system utilizes a network of cameras installed at parking spaces to detect real-time occupancy status—whether a space is occupied or vacant. The data collected from these cameras are transmitted to a centralized cloud-based platform for processing, enabling the delivery of various smart parking solutions. The rapid increase in vehicle usage, particularly in urban areas, has intensified the difficulty of finding available parking spaces, turning the process into a time-consuming and cumbersome ordeal. This underscores the necessity for automated systems that simplify the process of locating and reserving parking spots. In response, this research project proposes "Park Vision: Intelligent Parking Management System," a cost-effective, plug-and-play solution based on camera technology.

This system is designed to cater to diverse settings such as airports, IT companies, malls, college campuses, hostels, temples, and offices. Park Vision employs advanced techniques including Mapping techniques, Convolutional Neural Network (CNN) techniques, YOLOV5, and Threshold techniques to provide a comprehensive overview of parking lots and extract valuable parking space information. Additionally, Park Vision integrates machine learning and mapping technologies to streamline the parking process, thereby saving time and enhancing overall efficiency. A standout feature of Park Vision is its dynamic parking guidance capability. By utilizing real-time occupancy data and advanced algorithms, the system guides drivers to available parking spots through digital signs, mobile apps, and in-car navigation systems. This minimizes the time wasted circling for parking, thereby reducing traffic congestion and emissions. Furthermore, Park Vision offers the convenience of reserving and guaranteeing parking spots for users who book in advance through its dedicated mobile application. This study aims to explore how image processing can effectively tackle current issues in the parking system. It seeks to identify shortcomings in existing generations of intelligent parking systems and propose more efficient methods to address these challenges. In conclusion, Park Vision exemplifies a transformative approach to addressing the inefficiencies of current parking systems. By leveraging cutting-edge technology and innovative methodologies, Park Vision aims to revolutionize urban parking management, improve user experience, and contribute to the sustainable development of smart cities.

2. LITERATURE SURVEY

The incorporation of digital technologies in customer service is part of a broader trend, with smart parking systems becoming a significant focus area. Our initial survey explored foundational ideas relevant to our project, gathering information on technological stacks, algorithms, and potential shortcomings. This foundational knowledge is crucial for improving our project. Extensive research on smart parking lots has been conducted, differentiating various types of smart parking facilities based on their technological frameworks[3)].Smart

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parking systems typically integrate several technological components, including networking infrastructure, software, and sensors. Various studies have utilized different types of sensors, such as imaging devices [4)] ultrasonic sensors [5)], cellular sensors [6)], infrared sensors[7)], radar[8)], RFID[9)], laser-based smartphone sensors, and magnetometers [10)]. These sensors are chosen based on specific characteristics, such as detection capabilities, invasiveness, ease of installation, and the requirement for single or multiple sensors per parking slot. Several methods exist for locating cars in a parking lot. One technique involves using the Internet of Things (IoT) and Radio-Frequency Identification (RFID) to identify available parking spaces[11)]. IoT-based parking systems employ control devices, detectors, computers, and the internet to facilitate this process. Sensors installed in each parking space detect the presence of vehicles and relay this information to a microcontroller, which counts the number of empty spaces and displays this on an LED screen.

This allows drivers to determine the availability of parking spaces before entering the parking area. However, this technology faces challenges such as sensor inefficacy in adverse weather conditions and the high costs associated with installing sensors in every parking space. Additionally, maintaining sensor-based systems can be complex. Another method to detect vacant parking spaces involves using magnetic sensors that interact with the Earth's magnetic field [12)].Additionally, the hybrid approach was developed by two articles in the field of biometric-AI. The idea and creation of a platform with sensors for reliable and secure biometric authentication, where data was protected with a hybrid encryption method based on the RSA & Blowfish algorithms 41–46). The system has outstanding security thanks to the recommended two-step verification47–48). The facial imaging method, the RSA algorithm, and the FIF method are the three components of Face Information Fusion (FIF), a hybrid data fusion technique. The proposed technique might enable people to be identified rapidly 47-48).

3. CURRENT TRENDS IN SMART PARKING DESIGNS

3.1 IoT-Based Methods

One notable contribution to IoT-based smart parking systems was made by[13-20)]. Published by Blue Eyes Intelligence Engineering & Sciences Publication, their system uses signal strength and smartphone sensors for parking navigation. Sensors in each parking space provide real-time updates, enhancing parking management efficiency. Another significant approach is by [21-24)]. Detailed in the Turkish Journal of Physiotherapy and Rehabilitation, their vision-based system uses IR sensors to detect vehicle presence. It integrates a DC motor for gate operation, a WiFi modem for connectivity, and an AVR microcontroller to manage operations, presenting a comprehensive solution for parking management.

3.2 Visual Algorithm-Based Methods

Introduced a smart parking system using OpenCV in [25)] this method employs aerial images captured by cameras to monitor parking space occupancy, leveraging algorithms, Convolutional Neural Networks (CNN), and basic image processing techniques for efficiency. The study on autonomous parking space detection for electric vehicles, published by[27)]. Their

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system uses the improved YOLOv5OBB algorithm and a coordinate attention mechanism to enhance detection accuracy, which is particularly beneficial for autonomous parking applications. Additionally, a camera-based smart parking system, detailed in[27, 28]. Their solution uses perspective transformation techniques, including inverse perspective mapping [29, 30], the YOLOv5 algorithm, Canny edge detection, and the Dijkstra algorithm, ensuring precise detection and navigation within parking facilities. This literature survey highlights the evolution and diversification of smart parking technologies, emphasizing the integration of IoT, image processing, and advanced algorithms to enhance parking management systems. Both IoT-based and visual algorithm-based methods present their own sets of challenges, such as signal availability issues in weak or noisy areas and incompatibility with diverse wireless technologies. IoT-based methods, while reliable, can be costly due to the extensive need for sensors and devices. On the other hand, visual algorithm-based methods offer good performance. Given these considerations, we have chosen to implement visual algorithm-based methods and are developing a user-friendly interface to help users find parking slots with just a few clicks.

4. METHODOLOGY

4.1 Method of Research

The following outlines are our overall solution. When a car enters the parking lot, we employ object identification techniques (YOLOv5) and image processing to analyse the condition of the lot using surveillance camera footage. If no parking spaces are available, the system indicates "parking area is full." If spaces are available, the system directs the driver to the nearest parking spot and displays the number of available spaces. Once a driver parks, the system updates the status of the parking slots and displays the current availability at the entrance. The process of determining parking space availability includes the following steps: system initialization, input of live video stream, parking area coordinates, assignment of unique numerical labels to each parking spot, image frame acquisition, vehicle identification through object detection, parking lot availability check, and output display. A video camera, positioned above the cars at a height greater than 10 feet, records footage and determines parking space availability. A low-cost, portable wireless video camera is suitable for this purpose. The camera must be positioned to capture the entire parking area, as it needs to record the average pixel count of each car in the lot at all times.

4.2 Detailed Implementation

Our implementation requires real-world camera video as input. This input is pre-processed using masking technology, which divides the parking slots into equal rectangles. Masking optimizes space and resources in parking lots by creating a systematic layout, easing navigation, and reducing confusion and congestion. The pre-processed data is then used to train the YOLOv5 object detection algorithm, as illustrated in Figure 1.

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The YOLOv5 algorithm can be understood through its five essential components:

The input, an image or video frame, is pre-processed to meet the model's requirements, typically through resizing and normalizing pixel values. YOLOv5 uses a deep convolutional neural network (CNN) to extract features from the input image. Detect various features such as edges, textures, shapes, and objects. Normalizes outputs to improve training speed and stability. Apply non-linear transformations (typically Leaky ReLU) to enhance the model's capacity to learn complex patterns.

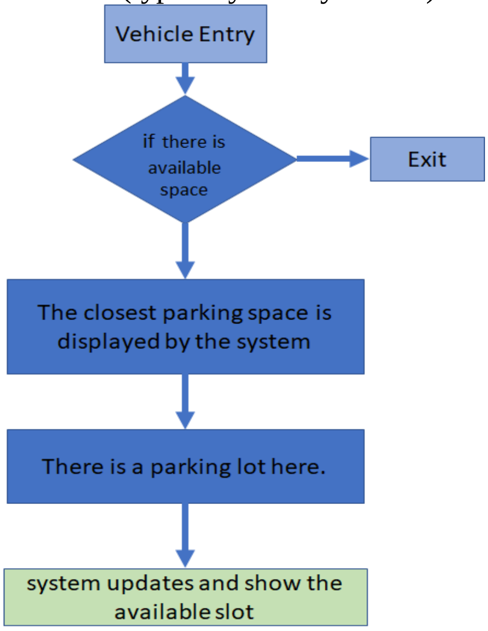

Figure 1: YOLOv5 object detection algorithm

As the image progresses through the convolutional layers, it is converted into feature maps, which contain information about the presence and location of features at different abstraction levels.

YOLOv5 uses anchor boxes to predict bounding boxes and class probabilities directly from the feature maps. NMS refines these predictions by predicting multiple bounding boxes for each object. Eliminating redundant or overlapping bounding boxes by selecting the one with the highest confidence score and suppressing others based on Intersection over Union (IoU) thresholds. The final output of the YOLOv5 model includes detected objects, each represented by a 2D bounding box, class label, and confidence score. Assigning a class label (e.g., 'car', 'person') based on the highest predicted probability. Providing coordinates (x, y, width, height) that define the location and size of each detected object within the image.

5. SYSTEM ARCHITECTURE

The system architecture encompasses the detailed workflow of our parking management model, as illustrated in Figure 2.

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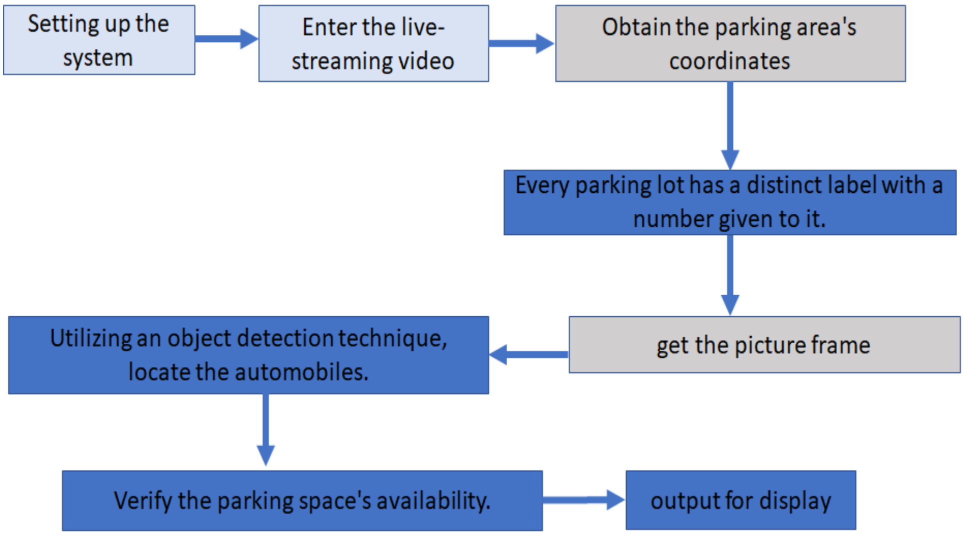

Figure 2: Parking management model

Videos serve as the primary input for the parking area system, providing a real-time and detailed view of the parking area. This continuous video feed enables the system to efficiently and accurately monitor and assess the status of available parking spaces.

Pre-processing techniques, such as masking, play a crucial role in enhancing the accuracy and effectiveness of the video analysis system. By isolating the parking spots through masking, the system filters out unnecessary information outside the designated areas. This reduces computational load and improves overall performance.

YOLOv5 is utilized for object detection, offering significant advantages in vehicle detection. Leveraging advanced algorithms and deep learning techniques, YOLOv5 can quickly and accurately identify various types of vehicles in images, regardless of size, orientation, or position within the frame. This precision is essential for applications where accurate vehicle detection is critical for decision-making.

To further enhance detection accuracy and efficiency, post-processing techniques such as non-maximum suppression (NMS) are employed. NMS refines the initially detected bounding boxes by eliminating redundant detections and improving the overall quality of the results. By selecting the most suitable bounding boxes and discarding those with excessive overlap, NMS ensures that the final output is refined and free of unnecessary duplicates, enhancing the reliability and precision of the detection algorithm.

The detected vehicles are analysed to determine the current parking status, identifying whether a parking spot is occupied or vacant. This comprehensive analysis includes comparing detected vehicles with a reference map of parking spots and considering additional criteria such as vehicle size and position. These techniques provide an accurate assessment of the parking status, offering valuable information for efficient parking management.

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The Flask API bridges the gap between the frontend and the backend, acting as a mediator that facilitates the flow of information between the two components. It handles requests from the frontend and communicates with the backend, ensuring smooth and efficient interaction between the user interface and the processing pipeline. This enables users to seamlessly access and manipulate parking status information through the frontend interface.

The primary role of the Flask API is to ensure efficient communication between the frontend and backend, allowing users to access and interact with parking status information seamlessly. This efficient interaction provides a user-friendly experience, enabling users to quickly find and utilize available parking spaces through the frontend interface.

5.1 Working of Yolov5 Algorithm

The YOLOv5 algorithm utilized in our project operates through several crucial stages: data loading, parking status initialization, drawing parking areas, car detection, updating parking status, and providing visual feedback and user interaction.

The system reads parking area coordinates from a file. Each parking area is defined by a series of points forming a polygon, which are used to map out each parking space on the video frame.

An initial status is set for each parking area, assuming all parking spaces are occupied (False). This status will be updated based on car detection results. The system employs computer vision techniques to draw parking areas on the video frame. Each parking area is drawn as a polygon using its coordinates. Each polygon is labelled with its identifier. The core functionality involves detecting cars in the video frame using an object detection model: A pre-trained machine learning model (e.g., YOLOv5) identifies cars and provides bounding boxes around them. Each bounding box includes the coordinates of the top-left and bottom-right corners, confidence score, and class label.

To determine if a car is parked in a given area, the following steps are taken: For each detected car, the center point of its bounding box is calculated. The center point is checked to see if it lies within the polygon of a parking area. If the center point is within a parking area, the algorithm further checks the overlap between the car's bounding box and the parking area's polygon. It calculates the ratio of the bounding box area to the polygon area.

If the overlap ratio exceeds a predefined threshold (e.g., 0.5), the parking space is considered occupied.

Based on the results of the above checks, if a car is detected within the bounds of a parking area and meets the overlap criteria, the parking status is set to occupied (False). If no car meets the criteria for a parking area, the status is updated to available (True). The video frame is updated in real-time to reflect the current parking status using the methods such as occupied spaces are typically shown in one color (e.g., red), and available spaces in another (e.g., green). Parking space identifiers and availability status are displayed on the frame.

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5.2 Mathematical Considerations:

Parking areas are represented as polygons defined by their vertices. Detected cars are represented by rectangular bounding boxes. This test determines whether a given point (car center) lies within a polygon (parking area).The area of the car's bounding box is compared to the area of the parking polygon to ensure substantial overlap, using the formula:

$$\mathrm{OR} = \mathrm{APP}/\mathrm{ABB} \qquad (1)$$

This comprehensive approach ensures the accurate and efficient detection of cars and the real-time updating of parking statuses.

5.3 Mathematical Analysis

The mathematical analysis involved in the YOLOv5-based parking detection system includes several key components: polygon representation, bounding box representation, point-in-polygon testing, and overlap ratio calculation.

Each parking area is represented as a polygon defined by its vertices. A polygon with n vertices can be represented as:

Polygon= {(x1, y1), (x2, y2) …, (xn, yn)}

Detected cars are represented by rectangular bounding boxes. A bounding box is defined by its top-left and bottom-right corners:

Bounding Box= {(xtl, ytl), (xbr, ybr)}

The center point (xc, yc) (x_c, y_c) (xc, yc) of the bounding box is calculated as:

$$xc = xtl + xbr / 2 \qquad (2)$$

$$yc = ytl + ybr / 2 \qquad (3)$$

To determine if a car is parked in a given area, the center point of its bounding box is checked to see if it lies within the polygon representing a parking area. This can be done using the ray-casting algorithm, which involves drawing a horizontal ray to the right of the point and counting how many times it intersects with the edges of the polygon.

Let PPP be the point (xc, yc) (x_c, y_c) (xc, yc), and V be the vertices of the polygon. The point PPP is inside the polygon if the number of intersections is odd, and outside if it is even. If the center point lies within the polygon, the algorithm further checks the overlap between the car's bounding box and the parking area's polygon. This involves calculating the intersection area between the bounding box and the polygon. To simplify, let's assume the parking area polygon can be approximated as a rectangle for overlap calculation. The overlap area is calculated as: Overlap Area=Area of Intersection (B, P) Where B is the bounding box and P is the parking area polygon. The ratio of the overlap area to the area of the parking polygon is given by:

$$OR = AI(B,P)/APP \qquad (4)$$

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A threshold is set to determine whether the overlap is significant enough to consider the parking space as occupied.

The center point (15, 15) lies within the rectangle (10, 10) to (20, 20).

The intersection of the bounding box and the parking polygon is itself a rectangle from (12, 12) to (18, 18).

Overlap Area = (18−12) × (18−12) =6×6=36

Area of Parking Polygon=(20−10)x (20−10)=10×10=100

Overlap Ratio=36/100=0.36, If the threshold is 0.45, the parking space would be considered available (False).This mathematical analysis ensures that each step of the YOLOv5-based parking detection system is grounded in precise calculations, enhancing accuracy and reliability.

5.4 The Dataset PKLot:

The set of data for this investigation came from the PKLot database. 13,509 photos of parking structures and 794,988 photos of carefully examined and numbered segmented parking places are included in the PKLot collection. The procedure for acquiring images is followed in order to obtain the parking spot dataset. A low-cost full high definition camera was used to record this procedure for over 30 days at a 3-min time-lapse period. The camera was mounted atop a building to reduce the possibility of occlusion between nearby cars. This is a brief synopsis of the dataset. Uncontrolled lighting was used to capture images that showed a range of weather situations, including bright, wet, and cloudy spells. Photos were captured from various parking lots, each with unique characteristics. A range of problems may be seen in the images, including perspective discrepancies, shadow effects, excessive sun exposure, poor light on wet days, etc. For every parking lot picture, an extended language markup (HTML) file with the position and status (occupied or unoccupied) of every parking space was produced.

Figure 3: PKLot dataset image with no border boxes

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Figure 4: PKLot dataset image

The designated boundary boxes and each parking slot's individual ID are displayed in the accompanying figure. Whereas the conventional system obtains its photographs from a video file, the online method gets its images directly from the camera. The following equation is used to gauge the recommended system's performance. Total Parking Spaces, Actual Number of Vehicles, and Expected Number of Vehicles are the three key terms.

$$\text{Perf1} = \frac{\text{Actual no of vehicles} - \text{Expected no of vehicles}}{\text{Total parking spaces}} * 100 \qquad (5)$$

This formula may be used to determine the suggested system's error percentage.

$$\%\text{error} = 100 * \frac{\text{Actual no of vehicles} - \text{Expected no of vehicles}}{\text{Expected no of vehicles}} \qquad (6)$$

The algorithm's performance was measured using a variety of photos taken in a range of weather conditions. The typical performance is found to be 90.03%. What kind of camera is being utilized to monitor the parking lot will also have an impact on how accurate the suggested system is. The algorithm's performance under various weather scenarios is displayed in the following table. The algorithm demonstrates the highest performance on Bright daytime, with an accuracy of 92.35%. On Overcast Day, the performance slightly decreases to 89.5%, while the lowest performance is recorded on gloomy day at 85.38%.

Environment Conditions	Total Slots Allotted	Real Number of Automobiles	Estimated Total Number of Vehicles	Progress
Bright daytime	90	88	81	92.35%
Overcast Day	80	78	59	89.5%
gloomy day	80	53	25	85.38%

6. CONCLUSION

A camera is employed in the project as an image sensor for the identification of video images. This is why the system can identify a sizable parking space at once and drive lots in any weather thanks to the usage of cameras. It is also affordable and effective. Depending on the area that has to be covered, one or more cameras may be employed for video image processing.

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Numerous sensors are crucial to the current automated parking system's operation. Thus, the suggested system only makes use of image processing techniques to automate parking using video captured by the parking lot's security cameras. These algorithms find unoccupied parking spots and notify the cars of their whereabouts.

Several cameras are all that are needed for this strategy to manage huge regions. To enhance performance, the camera's location might be changed. For optimal accuracy, every parking place must have its whole area captured by a camera. The guiding information display on this device provides drivers with helpful real-time parking lot information. In order to cut down on sensor costs and wiring headaches, this system is designed utilizing a combined image analysis methodology.

This research presents an enhanced YOLO v5 algorithm-based vehicle and parking spot identification technique. When the updated algorithm is used for parking space and vehicle detection, positive outcomes are obtained. This article employs different size feature maps for object identification, based on YOLO v5. Deeper networks may now extract more detailed information as a result. The system increases the accuracy of parking space and car recognition in the parking lot, according to experiments. However, the algorithm's detection effectiveness is somewhat impacted by variables like weather and lighting, thus more algorithmic development is required. Further study into creating the same model with many cameras is a potential direction.

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