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Research Article

SMART DETECTION SYSTEM FOR UNAUTHORIZED PARKING IN DISABILITY SPACES AT A UNIVERSITY: DESIGN, IMPLEMENTATION, AND PROTOTYPE VALIDATION

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ABSTRACT

Unauthorized occupation of parking spaces reserved for people with disabilities creates accessibility difficulties and increases the workload required for manual parking enforcement. This paper presents the design, implementation, and prototype validation of a low-cost smart detection system developed for disability parking spaces at King Abdulaziz University. The proposed system combines a Raspberry Pi 4, an Arducam IMX477 camera, a mobile permit-declaration application, English license-plate recognition, a SQLite database, a Flask-based administrative dashboard, evidence-image processing, and automated email notification. An authorized user scans a permit barcode through the mobile application and creates an active parking declaration. When a vehicle enters the monitored parking space, the Raspberry Pi detects its presence, confirms that it remains stationary for approximately 5 s, recognizes the English portion of the Saudi license plate using an OCR-based pipeline, and compares the result with the plate associated with the active declaration. Events are classified as authorized access, no-declaration violation, plate-mismatch violation, or technical detection issue. Prototype validation included vehicle-presence detection, stop-confirmation, authorization and violation classification, evidence quality and privacy processing, alert transmission, and continuous power and reliability testing. All six controlled vehicle-presence cases and all six stop-confirmation scenarios produced the expected behavior. Four authorization and violation test cases were also classified correctly. Evidence images were captured at 1920 × 1080 resolution, while four email-alert trials achieved successful delivery with an observed delay of 11 s per trial. During a two-hour continuous-operation test, the system consumed approximately 7.25 W on average and 10.25 W at estimated peak load, with an average Raspberry Pi temperature of 33.1°C and no observed under-voltage or thermal-throttling events. License-plate recognition was functional under controlled conditions but remained sensitive to lighting, distance, viewing angle, glare, blur, and plate visibility. The results demonstrate the feasibility of a low-cost edge-based system for supporting accessibility-parking enforcement while identifying license-plate recognition and long-term outdoor operation as the principal areas requiring further development.

Keywords: smart parking, disability parking, Raspberry Pi, license plate recognition, EasyOCR, computer vision, accessibility, QR permit, Flask, SQLite, edge computing.

INTRODUCTION

Accessible parking spaces are an essential part of an inclusive transportation environment because they provide people with disabilities with additional space and convenient access to buildings and facilities. Their effectiveness, however, depends on the spaces remaining available to authorized users. Unauthorized occupation can prevent eligible drivers from finding suitable parking and can create additional difficulties when entering or leaving a vehicle.

Misuse of accessible parking is not limited to a single institution. Cope and Allred reported substantial illegal use of handicapped parking spaces [1], while accessibility survey results cited by the Accessible Parking Coalition indicate that many people with disabilities experience difficulty locating available accessible parking [2]. Previous research has also suggested that enforcement based primarily on manual observation can be inconsistent and may allow repeated misuse [3].

This issue is relevant at King Abdulaziz University (KAU), where disability-parking enforcement has traditionally depended on security personnel visually inspecting vehicles for official permits. Information gathered from the university's General Administration of Security indicated that no automated parking-enforcement system was being used and that the existing database for people with disabilities was not directly linked to registered vehicle information. Consequently, continuous monitoring of every reserved space would require substantial manual effort.

Smart-parking research has introduced several technologies capable of automating parking-space monitoring, including wireless sensors, cameras, Radio Frequency Identification (RFID), QR codes, and Automatic Number Plate Recognition (ANPR). Nevertheless, many systems primarily address parking availability rather than determining whether the vehicle occupying a reserved accessibility space is authorized. Systems based on specialized readers or cloud-based recognition may also increase deployment cost and infrastructure requirements.

This work addresses these limitations through a low-cost system that combines **mobile-assisted permit declaration with camera-based physical vehicle verification**. Instead of attempting to read a permit sticker continuously using an external parking camera, the authorized driver scans a barcode through a mobile application. The mobile application creates a temporary declaration associated with the driver's registered license plate. A Raspberry Pi installed at the parking space then independently observes the physical vehicle and reads the English portion of its license plate. Authorization is granted only when the plate detected by the camera agrees with the plate contained in a valid active declaration.

The principal contributions of the work are:

1. Development of an edge-based disability-parking monitoring unit using a Raspberry Pi 4 and high-resolution camera.

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2. Separation of user permit declaration and physical vehicle verification through a mobile barcode workflow and camera-based license-plate recognition.
3. Introduction of stop-confirmation logic to prevent passing or maneuvering vehicles from unnecessarily triggering authorization processing.
4. Classification of parking events into authorized access, no-declaration violation, plate-mismatch violation, and technical detection issue.
5. Integration of evidence capture, privacy-oriented face blurring, SQLite event storage, a Flask administration dashboard, and automated email alerts.
6. Experimental evaluation of detection behavior, authorization logic, evidence generation, notification delay, and prototype power and reliability.

The objective is not to replace university security personnel, but to provide an automated monitoring and documentation tool that can increase the consistency of enforcement and allow personnel to focus on events that require human review.

RELATED WORK

A. Smart Parking and Occupancy Detection

Internet of Things technologies have been widely applied to parking management. Sadhukhan [4] presented an IoT-based smart-parking approach employing wireless sensing to determine parking availability. Such systems can reduce the time required to locate vacant parking spaces; however, occupancy detection alone cannot determine whether a particular driver is legally permitted to occupy a reserved accessibility space.

Camera-based systems provide additional information because the same sensing device can potentially identify occupancy, vehicle characteristics, and registration information. Kumar *et al.,* [5] described a Raspberry Pi-based vision-enabled parking approach in which camera processing was used for parking monitoring. Camera-based platforms are attractive for low-cost prototypes because processing can be conducted locally without installing a sensor beneath or beside every vehicle.

For accessibility enforcement, however, simply establishing that a parking space is occupied is insufficient. The system must establish a relationship between the physical vehicle and an authorization record.

B. Vehicle Authorization Technologies

QR-code, RFID, and license-plate recognition technologies represent three possible approaches to vehicle authorization.

QR-based access control can provide inexpensive digital identification. Li and Wang [6] reported a QR-code-based access-control approach for smart-campus environments. QR codes require relatively inexpensive hardware because they can be scanned using conventional cameras or smartphones. Their principal limitation for parking-space monitoring is that a code must be visible and positioned appropriately if it is to be recognized automatically by a fixed external camera.

RFID enables contactless identification without requiring optical line-of-sight. Singh *et al.,* [7] presented an RFID-enabled smart-parking gate system. RFID is convenient for automatic vehicle identification, but deployment requires a reader and tags for authorized vehicles. Reader positioning and detection range must also be controlled to prevent identification of vehicles outside the intended parking area.

ANPR identifies a vehicle directly from its registration plate. Tabrizi and Yousefi [8] demonstrated real-time plate recognition using OpenCV-based computer vision. ANPR provides an important advantage for enforcement because the identifier belongs to the physical vehicle being observed. Its main challenge is sensitivity to camera resolution, plate size in the image, viewing angle, illumination, reflection, dirt, obstruction, and motion blur.

C. Accessibility-Specific Enforcement

Smart enforcement of disability parking has received less attention than general parking-space management. Previous studies and accessibility reports indicate that unauthorized use remains a practical problem [1]–[3]. Al-Nuaim *et al.,* [9] described an IoT-based approach to smart enforcement of disabled parking. Cloud-connected approaches can provide sophisticated processing, although continuous network and cloud-service requirements may increase cost and deployment complexity.

The system proposed in this work attempts to combine the advantages of multiple approaches while limiting infrastructure requirements. A QR/barcode establishes the user's permit declaration through a mobile application, while license-plate recognition separately confirms the identity of the vehicle occupying the monitored space. Processing is primarily performed at the network edge, and the prototype does not require a commercial cloud ANPR platform or dedicated RFID infrastructure.

SYSTEM REQUIREMENTS AND DESIGN

A. Design Objectives

The system was designed around several functional and engineering objectives. It had to detect vehicle occupation, verify authorization, maintain evidence, notify security personnel, operate using low-voltage power, and remain sufficiently inexpensive for a university prototype.

Important design targets included:

Requirement	Design Target
Vehicle detection	Reliable operation under daylight and artificial lighting
License-plate verification	Recognition of English portion of plate and comparison with active declaration
Alert transmission	Approximately ≤12 s including prototype delivery
Evidence	At least 720p with event information
Authorization	Mobile barcode declaration associated with registered plate
Privacy	Face blurring when faces are detected; limited data retention
Environmental protection	IP65-rated enclosure
Power	5 V DC; ≤8 W average and ≤12 W peak
Hardware budget	≤3000 SAR
Safety	Low-voltage operation without physical hazards

The hardware estimate for the complete design was approximately 1150–1550 SAR, leaving margin below the 3000 SAR project budget.

B. System Architecture

The implemented prototype is organized into three logical layers: sensing, edge processing, and backend/administration.

The **sensing layer** consists primarily of an Arducam IMX477 high-quality camera. The camera's 12.3-megapixel sensor can capture images up to 4056 × 3040 pixels and is connected directly to the Raspberry Pi through the CSI interface.

The **edge-processing layer** consists of a Raspberry Pi 4 Model B. Python-based modules on the Raspberry Pi perform continuous camera acquisition, vehicle detection, parked-state confirmation, plate recognition, decision making, evidence generation, and communication with the backend.

The **backend and administration layer** runs on a laptop during prototype testing. It contains the SQLite database and Flask dashboard. The mobile application also communicates with this layer when an authorized user creates an active parking declaration.

The prototype operates over a local Wi-Fi network. This allows vehicle images, declarations, detected plates, and violation information to remain within the local environment rather than being continuously transmitted to an external cloud service.

C. Mobile Permit Declaration

Each authorized permit contains a barcode or QR identifier linked to a database permit record. Instead of positioning the barcode for a fixed parking camera, the barcode is installed in a protected location inside the vehicle, such as near the windshield or sun visor.

Before or during arrival, the authorized user scans the permit with the mobile application. A successful scan creates an **active declaration session** containing the permit and registered vehicle information.
A declaration is considered valid when:

- an active declaration exists;
- the declaration has not expired;
- it corresponds to the monitored location or parking zone;
- the detected license plate matches the declared plate; and
- The declaration is within its allowed session period.

This architecture avoids requiring the external parking camera to recognize both a barcode and a license plate simultaneously.

IMPLEMENTATION

A. Vehicle Detection and Region of Interest

Continuous processing of an entire high-resolution frame would increase computational load and increase the possibility of triggering on unrelated objects. Therefore, a Region of Interest (ROI) is configured around the monitored parking space and the expected vehicle-front area.

Calibration consists of capturing the empty parking bay, placing a test vehicle within the space, adjusting the camera until the front of the vehicle and license plate are visible, and defining an ROI around the useful area. The resulting coordinates are stored in the system configuration.

Vehicle presence acts as the initial trigger. When no vehicle is detected, the system remains in continuous monitoring mode. When a vehicle enters the ROI, processing advances to parked-state confirmation rather than immediately creating an event.

B. Stop-Confirmation Logic

Vehicles may temporarily enter the camera view while passing, reversing, or maneuvering. Treating every temporary presence as a parking event could create false records and unnecessary OCR processing.

To reduce this problem, the prototype employs a stability period of approximately **5 s**. When a vehicle is detected inside the ROI, the system starts a timer. If the vehicle remains visible and sufficiently stable for approximately 5 s, it is considered parked and the license-plate recognition process begins. If it leaves the ROI before the interval expires, the temporary event is discarded.

This threshold is configurable so that it can be increased or decreased for different parking layouts.

C. License-Plate Recognition

After parked-state confirmation, the system attempts to recognize the English portion of the Saudi license plate. The main processing sequence is:

1. Capture a camera frame.
2. Identify the relevant plate region.
3. Crop the English row.
4. Apply image preprocessing.
5. Perform OCR.
6. Clean and normalize the recognized text.
7. Compare the result with the plate contained in the active declaration.

Open CV-based preprocessing can include grayscale conversion, resizing, contrast enhancement, thresholding, and filtering. Easy OCR is used for character recognition. The OCR result is normalized by converting it to uppercase and removing spaces, symbols, and other non-alphanumeric characters.

For example, normalized plate identifiers used during testing included RBR2144, LAS6914, and DJT5166.

To reduce decisions based on a single poor frame, recognition can be attempted up to three times. The overall recognition period is limited to approximately one minute. If the plate remains unreadable after the permitted retries or timeout, the event is classified as a **technical detection issue** rather than automatically treating the driver as an unauthorized user.

D. Authorization and Decision Logic

After successful plate recognition, the normalized detected plate is compared with active declaration records.
The principal logic is:

Case 1: No vehicle detected. The system continues monitoring.

Case 2: Vehicle detected but not confirmed as parked. The temporary event is ignored.

Case 3: Parked vehicle but plate cannot be recognized. The system records a technical detection issue.

Case 4: Plate recognized but no valid active declaration exists. The system records a no-declaration violation.

Case 5: Active declaration exists but declared and detected plates differ. The system records a plate-mismatch violation.

Case 6: Active declaration exists and both plates match. The event is recorded as authorized.

Plate mismatch provides an additional protection against permit misuse because a person cannot simply create a declaration for one registered vehicle and then occupy the parking space using another vehicle.

E. Evidence Capture and Privacy

Violation and technical events generate an evidence image associated with the corresponding database record. The evidence record can contain:

- timestamp;
- camera or zone identifier;
- detected plate;
- declared plate, when applicable;
- event type;
- decision result;
- image path;
- alert status; and
- Location information.

Evidence testing used images at 1920 × 1080 resolution, exceeding the minimum 720p design requirement.

The camera may also capture people near a vehicle. To reduce unnecessary exposure of personal information, the evidence-processing stage includes automatic face detection and blurring. When a face is detected, the detected region is blurred before the image is stored or transmitted as an alert attachment. If no face is identified, the image can be stored without modification.

The system design additionally proposes limiting record retention and restricting administrative access to authorized devices.

F. Database and Dashboard

SQLite was selected for the final prototype because it allows the backend to operate without a separate database-server installation. The database maintains information including permits, active sessions, violations, alerts, detection logs, audit logs, configuration settings, and system-status records.

A Flask web application provides the administrative interface. Its functions include viewing:

- overall system status;
- permit records;
- active mobile declarations;
- detected violations;
- evidence images;
- system logs;
- live camera information; and
- configurable settings.

SQLite provides adequate simplicity for a single prototype detector and backend; however, a larger deployment with numerous simultaneous detection units would benefit from more scalable database architecture.

G. Alerting

When the final decision represents a violation or technical issue, the system creates a corresponding event record and sends an email alert. The email is intended to contain the event type, timestamp, location or map information, recognized plate when available, and evidence attachment.

Alert handling is separated from the main monitoring process so that communication operations do not unnecessarily stop acquisition of camera frames.

EXPERIMENTAL VALIDATION

The prototype was evaluated through a series of controlled experiments covering different stages of the system pipeline.

A. Vehicle-Presence Detection

Six controlled scenarios were performed:

1. Empty space under daylight.
2. Centered vehicle under daylight.
3. Slightly angled vehicle under daylight.
4. Empty space under artificial lighting.
5. Centered vehicle under artificial lighting.
6. Vehicle near, but outside, the ROI.

The system produced the expected result in all six scenarios. Empty-space cases remained empty, vehicles positioned within the parking area were detected, and a vehicle located outside the ROI was ignored.

These tests establish that the configured ROI and detector were functionally capable of activating the subsequent processing stages under the tested conditions.

B. Stop-Confirmation Test

Six scenarios were used to evaluate passing, maneuvering, and parked vehicles.

A vehicle present for less than 5 s was expected to be ignored or to produce no final decision. A vehicle remaining for more than 5 s was expected to initiate OCR and eventually produce a classified event.

Scenario	Time in ROI	Expected	Observed
Empty space	0 s	No event	No event
Passing vehicle	<5 s	Ignore	Ignored
Vehicle enters then leaves	<5 s	Ignore	Ignored
Vehicle stops briefly	<5 s	No final decision	No final decision
Vehicle parks normally	>5 s	Begin OCR	OCR initiated
Vehicle remains parked	>5 s	Classify event	Event classified

All six scenarios passed, demonstrating that the stability timer can prevent short-duration vehicle movement from immediately entering the authorization workflow.

C. Authorization and Violation Classification

Four decision scenarios were examined.

In the first test, a vehicle was parked without an active declaration. The system returned **Violation: No Declaration**.

In the second test, an active declaration existed but the detected plate differed from the plate associated with the declaration. The system returned **Violation: Plate Mismatch**.

In the third test, an active declaration existed and the detected plate matched the declaration. The system returned **Authorized** and generated no violation alert.

A fourth test involved reverse parking without an active declaration. The event was again classified as **No Declaration**.

All four tested decision scenarios produced the expected classifications.

D. Evidence Quality and Privacy

Evidence was evaluated for no-declaration, reverse-parking, plate-mismatch, and authorized cases. Violation evidence was recorded at **1920 × 1080**, with the timestamp and vehicle information available for review. Evidence was accessible through the dashboard and attached to violation email messages when required.

Face blurring was configured to operate automatically when a face was detected. The evidence results therefore satisfied the prototype's image-resolution and privacy-processing objectives.

E. Alert Transmission

Four no-declaration trials were performed to evaluate automated email delivery. In each case, an evidence image was attached successfully.

Trial	Detection Time	Email Time	Delay
1	21:55:06	21:55:17	11 s
2	21:56:42	21:56:53	11 s
3	21:58:16	21:58:27	11 s
4	21:59:50	22:00:01	11 s

All four alert messages were delivered, corresponding to a **100% delivery rate for the four prototype trials**. The observed delay was 11 s, which met the prototype target of approximately 12 s.

An implementation issue was nevertheless identified in the email contents. Although the violation and evidence were generated correctly, some messages displayed the violation type as "Unknown," the plate as "Not captured," and the QR information as "Not found." This indicates that the transmission channel operated successfully but that the backend-to-template metadata mapping requires correction.

F. Power and Reliability

The complete system was operated continuously for two hours with the camera and detection software active and the dashboard connected.

The measured electrical values were:

$$P_{avg}=V I_{avg}$$

$$P_{avg}=5.0=7.25;W$$

And

$$P_{peak}=V I_{max}$$

$$P_{peak}=5.0=10.25;W.$$

The results are summarized below.

Parameter	Observed Value
Test duration	2 h
Input voltage	5.0 V
Average current	≈1.45 A
Maximum current	≈2.05 A
Average power	≈7.25 W
Estimated peak power	≈10.25 W
Average temperature	33.1°C
Under-voltage warning	None
Thermal throttling	None
Unexpected crash/shutdown	None

Average power remained below the 8 W target and estimated peak power remained below the 12 W target. No under-voltage warning or thermal throttling was observed during the two-hour period.

G. Overall Validation Results

A condensed summary of prototype performance is presented below.

Function	Prototype Result	Status
Vehicle presence detection	6/6 controlled cases behaved correctly	Pass in tested cases
Stop-confirmation	6/6 scenarios behaved correctly	Pass
English plate recognition	Functional under suitable controlled conditions	Partial Pass
Authorization logic	Tested authorized, no-declaration and mismatch cases correctly	Pass
Evidence	1920 × 1080 with metadata	Pass
Face privacy processing	Automatic blurring when face detected	Implemented
Mobile declaration	Active session generated from permit scan	Pass
Email delivery	4/4 alerts delivered	Pass
Alert delay	11 s observed	Pass
Average power	7.25 W	Pass
Peak power	10.25 W	Pass
Two-hour operation	No shutdown, under-voltage, or throttling	Pass
Hardware cost	Approximately 1150–1550 SAR	Within budget

The most significant incomplete requirement was license-plate recognition. Easy OCR worked when plates were sufficiently clear and properly positioned but performance decreased under adverse imaging conditions.

DISCUSSION

The experimental results demonstrate that the proposed architecture can integrate mobile authorization and camera-based vehicle verification within a relatively low-cost embedded platform. The most important feature of the final implementation is the separation between **declaration** and **verification**.

The mobile application establishes that an authorized user intends to occupy the accessibility space, but this declaration alone is not accepted as proof that the registered vehicle is present. The Raspberry Pi independently observes the vehicle and compares its license plate with the declaration. This two-stage approach reduces the limitations of a QR-only system and provides greater resistance to permit sharing or misuse.

The stop-confirmation mechanism is also important in practice. A parking camera can observe pedestrians, nearby traffic, and vehicles performing short maneuvers. Delaying authorization processing until a vehicle remains within the ROI for approximately 5 s reduces unnecessary OCR operations and the probability that passing vehicles create false events.

The experiments further demonstrate that the selected embedded platform is adequate for the prototype's computational and electrical requirements. A measured average consumption of approximately 7.25 W indicates that the Raspberry Pi, camera, and related processing can operate within the project's low-power design target. Likewise, two hours of continuous operation without under-voltage or thermal throttling provides initial evidence of prototype stability.

The evidence and alert pipeline also provides a practical benefit over occupancy-only systems. Security personnel receive a persistent database record and visual evidence rather than a simple occupied/unoccupied indication. Face blurring additionally introduces a privacy mechanism intended to limit unnecessary identification of people within the camera view.

Despite these promising results, the prototype should not yet be interpreted as demonstrating deployment-level detection accuracy.
First, the vehicle-presence experiment included only six controlled scenarios. Although all six produced the correct outputs, the original design specification proposed verification using a substantially larger number of detection events. Consequently, the present result demonstrates **functional feasibility under the tested conditions**, not a statistically established field accuracy of 95% or greater.

Second, license-plate recognition remains the system's primary technical limitation. Successful recognition depends heavily on plate pixel size, camera angle, distance, exposure, glare, lighting, dirt, obstruction, and blur. The system successfully recognized plates under suitable controlled conditions, including the test plate RBR2144, but other tests showed reduced reliability for plates such as LAS6914 and DJT5166. The license-plate function should therefore be considered prototype-ready but not deployment-ready.

Third, outdoor environmental testing remains limited. An IP65 enclosure was selected and temperature was monitored, but extended operation in direct sunlight, high ambient temperature, dust, rain, glare, shadows, and nighttime conditions was not comprehensively evaluated.

Fourth, the current architecture depends on LAN connectivity between the Raspberry Pi, mobile application, and laptop backend. A network interruption could temporarily prevent declaration verification. Local event buffering and later synchronization would improve robustness.

Fifth, the prototype used fallback location information because the planned USB GPS module was unavailable. A permanent installation could instead assign fixed verified coordinates to each parking-space unit, potentially eliminating the need for a GPS receiver altogether.

Finally, the four alert trials demonstrated reliable email delivery, but missing metadata in the email template must be corrected before operational deployment. Authentication and access control for the web dashboard and API endpoints should likewise be strengthened before the system handles real user and vehicle information.

SOCIAL, ECONOMIC, SAFETY, AND PRIVACY IMPACT

The primary social benefit of the proposed system is improved accessibility. Reserved disability spaces have value only when they remain available to the people for whom they are intended. Continuous automated monitoring can assist campus security in responding to misuse more consistently than occasional patrols alone.

Economically, the prototype was designed around commercially available embedded hardware and open-source software. Its estimated hardware cost remains considerably below the project ceiling of 3000 SAR. Avoiding dedicated UHF RFID readers and commercial cloud ANPR platforms further reduces infrastructure requirements.

The system also has a comparatively modest energy requirement. Edge processing reduces the need to continuously upload high-resolution video to cloud services and allows most decisions to be made locally.

From a safety perspective, the device operates at 5 V DC and does not require mechanical gates, barriers, or other moving equipment around vehicles and pedestrians.

Privacy is especially important because vehicle monitoring involves license-plate information and may unintentionally capture people. The camera should therefore be directed only at the required parking area, evidence storage should be minimized, face blurring should be applied when appropriate, database access should be restricted, and old records should be deleted according to an established retention policy.

FUTURE WORK

Several improvements are necessary before large-scale deployment.
The highest priority is the license-plate recognition module. Future implementations should evaluate models trained specifically for Saudi license plates and systematically optimize camera focal length, mounting position, viewing distance, and exposure. Improved pre-processing and glare reduction may further increase OCR reliability.

A substantially larger dataset should also be collected. Tests should include numerous vehicles, plate formats, parking orientations, times of day, sunlight conditions, artificial illumination, glare, shadows, dust, and partially obstructed plates. This would allow calculation of meaningful detection, recognition, false-positive, and false-negative rates.

Long-duration outdoor reliability experiments are also necessary. Continuous multi-day operation should be used to evaluate temperature, CPU and memory utilization, storage growth, network stability, power behavior, database reliability, and enclosure effectiveness.

The communication architecture should support temporary loss of network connectivity. The Raspberry Pi could save events, declarations cached within an allowed validity interval, and evidence locally, and then synchronize these records after communication is restored.

Security hardening should include authenticated dashboard access, protected API endpoints, secure mobile-app authentication, environment-variable management for credentials, encrypted communication, and stricter authorization of administrative functions. The email-alert interface should be corrected so that violation type, detected plate, declared plate, location, timestamp, and evidence are populated consistently.

Finally, the platform should be extended from a single prototype space to multiple parking spaces. Each Raspberry Pi unit can be assigned a unique camera_id, zone_id, or parking_space_id, allowing a centralized dashboard to display the state and alerts of multiple accessibility spaces across the university.

CONCLUSION

This paper presented a low-cost smart detection system designed to support enforcement of disability parking spaces at King Abdulaziz University. The final implementation integrates a Raspberry Pi 4, high-resolution camera, mobile barcode declaration workflow, English license-plate recognition, SQLite database, Flask dashboard, and evidence generation, privacy processing, and automated email alerts. The proposed workflow separates permit declaration from physical vehicle verification. An authorized user first creates an active declaration by scanning a permit barcode using the mobile application. The Raspberry Pi subsequently detects the parked vehicle, reads the English portion of its license plate, and compares that plate with the declaration. Depending on the comparison and recognition outcome, the event is classified as authorized access, no-declaration violation, plate-mismatch violation, or technical detection issue.

Controlled prototype experiments demonstrated correct behavior for the tested vehicle-presence, stop-confirmation, and authorization scenarios. Evidence images satisfied the required resolution, and all four email-alert trials were delivered with an observed 11-s transmission delay. The system also operated continuously for two hours at approximately 7.25 W average powers and 10.25 W estimated peak powers, with an average Raspberry Pi temperature of 33.1°C and no observed under-voltage or thermal-throttling events.

The principal remaining limitation is license-plate recognition. Although the OCR pipeline can recognize suitable plates under controlled conditions, its accuracy remains dependent on illumination, distance, viewing angle, plate clarity, glare, and image quality. Larger-scale outdoor evaluation is therefore required before permanent operational deployment.

Overall, the prototype demonstrates that combining mobile permit declaration with independent edge-based license-plate verification can provide a practical foundation for automated accessibility-parking enforcement. With improved plate recognition, stronger network and security mechanisms, extended field validation, and multi-space scalability, the architecture could be developed into a campus-wide monitoring system and potentially adapted to hospitals, shopping centers, public facilities, and other environments where reliable accessibility-parking enforcement is required.

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