

PAPER

Knowledge-Based IoT Framework for Smart Campus Management: Design, Implementation, and Prototype Validation of Integrated Parking, Lighting, and Waste Systems

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ABSTRACT

Smart campus systems use Internet of Things (IoT) technologies to enhance campus services, reduce resource waste, and support sustainable development. This paper proposes a knowledge-based IoT framework for smart campus management. The framework focuses on three main subsystems: (1) smart parking, (2) smart lighting, and (3) smart waste management. These subsystems are integrated through a centralized knowledge base that analyzes collected data and supports effective decision-making. The smart parking system uses sensors and camera-based recognition to identify available parking spaces, guide users to free locations, and support pre-booking of parking spots. This approach helps reduce traffic congestion and the time spent searching for parking. The smart lighting system relies on environmental and motion sensors to automatically control lighting based on real-time conditions. In addition, it supports automatic scheduling for classrooms and teacher-based control, which contributes to significant energy savings. The smart waste management system monitors waste bin fill levels using sensors and sends alerts when collection is required, improving waste collection efficiency and maintaining campus cleanliness. All sensor data are collected and processed on a central platform, where a knowledge-based layer applies predefined rules to enable automated actions and system control. The proposed framework was implemented as a prototype and applied in a campus-like prototype environment to evaluate its performance. The results show improved operational efficiency, reduced energy consumption, and better overall campus management. This study confirms that integrating IoT technologies with a knowledge-based approach offers a practical and scalable solution for smart campus systems and supports the development of sustainable and intelligent campus environments.

KEYWORDS

smart parking, Internet of Things (IoT), license plate recognition, cloud computing, real-time monitoring, solar energy, urban mobility, reservation system, M2M services innovation, smart cities

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1 INTRODUCTION: INTEGRATED SMART CAMPUS MANAGEMENT SYSTEMS

Smart cities represent a new model in urban development by integrating advanced technologies across multiple sectors [1]. The Internet of Things (IoT) technology plays a crucial role in smart cities, enabling the interconnection of various urban systems [2]. Smart cities are characterized by several innovative systems that differentiate them from traditional urban areas. Among these systems are Smart Traffic Management Systems, Smart Energy Management Systems, Smart Environmental Monitoring Systems, and Smart Infrastructure Management Systems [1–2].

IoT refers to a network of physical objects equipped with a variety of sensors, software, and technology [3]. It enables the connection of these systems and devices over the Internet to exchange data in real-time [4]. IoT is rapidly becoming a ubiquitous reality in modern urban environments. With increasing numbers of intelligent devices connected to the internet, the presence of IoT can be observed in every aspect of daily urban operations [4].

Egypt has experienced rapid urban expansion, with the development of its cities continuing at a remarkable pace [5]. Over the past few years, more than thirteen new cities have been established, many designed as smart cities, with continuous efforts underway to implement further technological advancements [5–6]. As Egypt continues to modernize its educational infrastructure, this has made it imperative to implement efficient campus management solutions. Universities often face multiple operational challenges due to high daily traffic from students, faculty, and staff, leading to congestion, resource wastage, and environmental concerns [6].

1.1 Smart parking systems in universities

Traditional parking systems are increasingly incapable of efficiently managing the growing demand for parking spaces, which affects campus mobility and overall convenience. Smart parking systems in universities can play a crucial role in mitigating these parking challenges [7]. The integration of IoT in parking systems offers a transformative approach by providing real-time monitoring of available parking spaces, automated guidance systems, and data-driven parking management [7–8]. These systems utilize sensors, cameras, and mobile applications to streamline the parking experience, reducing the time spent searching for spaces and minimizing traffic congestion within campus premises.

1.2 Smart lighting management systems

Universities face significant challenges in managing energy consumption across their expansive campuses, with lighting systems accounting for a substantial portion of energy usage [7]. Traditional lighting systems operate on fixed schedules regardless of actual occupancy, leading to energy wastage and increased operational costs. Smart lighting systems in universities represent a critical component of sustainable campus management [9]. The implementation of IoT-based lighting control enables automatic adjustment based on occupancy detection, natural light levels, and scheduled activities [10]. These systems incorporate motion sensors, ambient light sensors, and programmable controls to optimize energy usage while maintaining adequate illumination for safety and learning environments.

1.3 Smart waste collection systems

The management of waste on university campuses presents unique challenges due to the high volume of waste generated daily and the need for efficient collection processes [11]. Traditional waste management relies on fixed collection schedules, often resulting in either overflowing bins or unnecessary collection trips. Smart waste management systems in universities leverage IoT technology to revolutionize waste collection efficiency [12]. By integrating ultrasonic sensors for fill-level monitoring, automated vacuum collection systems, and real-time data analytics, these systems optimize collection routes and schedules [13]. The implementation of touchless operation through proximity sensors also enhances hygiene standards, which has become increasingly important in educational environments.

This paper presents an integrated smart campus management system based on IoT within a university context, which combines smart parking, intelligent lighting control, and automated waste collection to create a comprehensive solution for modern campus operations.

The operation planning of these IoTs needs a comprehensive knowledge base. This knowledge base is presented too.

The remaining sections of this paper are organized as follows: Section 2 presents related work, reviewing existing smart parking, lighting, and waste management systems in university contexts. Section 3 details the knowledge base governing the integrated system's operation. Section 4 presents the implementation of IoT prototypes. Finally, Section 5 presents the conclusion, summarizing the achievements and future directions of this integrated smart campus management system.

2 RELATED WORK

Akram Elomiya et al. (2023) proposed a fuzzy-logic parking recommendation system integrating Google Maps and OpenCV to optimize spot selection on university campuses [14]. Their model achieved 92% accuracy in real-time recommendation tasks.

Kristína Kováčiková et al. (2021) examined smart parking as part of smart airport ecosystems, using survey data to evaluate traveler experience and infrastructure integration [15]. Results emphasized user comfort and digital service expectations.

M. Alymani (2025) reviewed IoT-enabled smart parking frameworks, emphasizing sensor fusion and AI-driven prediction models for traffic reduction [16]. The study noted data privacy risks and interoperability challenges in heterogeneous urban infrastructures.

B. S. Alsafar (2024) proposed an RFID and cloud-based Smart Parking Management System for real-time slot allocation [17]. Results demonstrated improved efficiency but highlighted scalability issues and high setup costs.

S. Khemakhem et al. (2024) conducted a survey of IoT-based smart street-lighting systems, identifying adaptive sensing and wireless networks as key enablers of energy savings [18]. Deployment obstacles included calibration drift, latency, and maintenance overhead.

A. A. Mamun (2024) developed an ultrasonic sensor-based IoT Smart Parking prototype connected to cloud services [19]. Accurate occupancy detection was achieved, though environmental noise and hardware durability limited outdoor applications.

Waheb A. Jabbar et al. (2024) introduced a LoRaWAN-based Smart Parking Management System utilizing magnetic and ultrasonic sensors connected to

Arduino UNO [20]. Their mobile application enabled remote monitoring and low-power data transmission, showing improvements in communication efficiency and maintenance cost reduction.

S. Aswath (2025) introduced an IoT-enabled smart parking system with online reservation capabilities via mobile applications [21]. The model reduced search time and enhanced user satisfaction, yet cybersecurity and reliability under heavy traffic remained critical concerns.

M. Sumathi (2025) applied IoT-based smart bins with cloud analytics for campus waste management [22]. The system improved collection efficiency, but issues in sensor maintenance and real-time synchronization persisted.

F. Messina et al. (2025) evaluated lightweight IoT protocols for urban parking management, demonstrating reduced latency and energy consumption compared to conventional approaches [23]. Security weaknesses in protocol design were highlighted as key future challenges.

W. A. Jabbar (2025) investigated solar-powered LED lighting with IoT and LoRaWAN for smart campuses [24]. The framework achieved energy efficiency, while long-range communication reliability and legacy system integration were identified as limitations.

3 KNOWLEDGEBASE: INTEGRATED CAMPUS MANAGEMENT SYSTEM—COMPLETE RULES

The following are some of the main rules that govern

3.1 Smart parking system rules

Entry system rules

Rule 1: QR Code Entry

IF QR code is scanned AND QR code is valid AND booking exists AND booking is active then

- Update booking status to “entered”
- Update spot status to “busy” in database
- Display updated data on GUI
- Switch ON the entry gate
- Display “Welcome [Username]” on LCD
- Start counting parking time and cost
- Log entry transaction
- TRIGGER: Classroom pre-activation if teacher (See Lighting Rule 4)

ELSE

- Switch OFF the gate
- Display “Access Denied” on LCD
- Show error message on GUI

END IF

Rule 2: Spot Sensor Entry

IF spot sensor detects vehicle AND spot status == “booked” then

- Update spot status to “busy” in database
- Update booking enter time to NOW()
- Display updated data on GUI
- Start counting parking time and cost
- Log entry transaction
- Show notification “Vehicle Entered Spot X”

```

ELSE IF spot sensor detects vehicle AND spot status == "free" then
    Update spot status to "busy" in database
    Create emergency booking record
    Display updated data on GUI
    Start counting parking time and cost
    Log unauthorized entry transaction
    Show alert "Unauthorized Vehicle in Spot X"
END IF

```

Parking spot management rules

Rule 3: Booking Creation

```

IF user creates booking AND spot is "free" AND payment is valid then
    Update spot status to "booked" in database
    Create booking record with expiration time
    Display updated data on GUI
    Generate QR code for user
    Send confirmation to user
    Log booking transaction
    Start expiration countdown timer
ELSE
    Display "Spot Not Available" error
    Suggest alternative spots
END IF

```

Rule 4: Booking Expiration

```

IF booking time > expiration time AND vehicle has NOT entered
    Update booking status to "expired"
    Update spot status to "free" in database
    Display updated data on GUI
    Charge cancellation fee
    Log expiration transaction
    Send expiration notification to user
ELSE IF booking time > expiration time AND vehicle HAS entered then
    Update booking status to "overstayed"
    Continue counting time and cost
    Display overstay warning on GUI
    Apply overstay charges
    Log overstay transaction
END IF

```

Rule 5: Vehicle Exit

```

IF exit button is pressed OR exit sensor detects vehicle leaving then
    Calculate total parking cost
    Update booking status to "completed"
    Update spot status to "free" in database
    Display updated data on GUI
    Switch ON exit gate
    Display "Total: £X.XX" on LCD
    Process payment
    Log exit transaction
    Send receipt to user
    IF user is teacher then
        TRIGGER: Classroom deactivation check (See Lighting Rule 5)
    END IF

```

```

ELSE
    Keep gate closed
    Display current charges on LCD
END IF

```

Safety monitoring rules

Rule 6: Temperature Safety

```

IF temperature > 60°C then
    Update GUI status to "DANGER" (RED)
    Display critical temperature alert
    Trigger emergency alarm
    Log critical safety event
    Send emergency notifications
ELSE IF temperature > 45°C then
    Update GUI status to "WARNING" (YELLOW)
    Display temperature warning
    Log warning event
ELSE
    Update GUI status to "NORMAL" (GREEN)
    Continue normal operation
END IF

```

Rule 7: Gas Level Safety

```

IF gas_level > 700 ppm then
    Update GUI status to "DANGER" (RED)
    Display "EVACUATE IMMEDIATELY" alert
    Trigger emergency alarm
    Log critical safety event
    Send emergency notifications
ELSE IF gas_level > 500 ppm then
    Update GUI status to "WARNING" (YELLOW)
    Display gas warning
    Log warning event
ELSE
    Update GUI status to "NORMAL" (GREEN)
    Continue normal operation
END IF

```

Rule 8: Fire Detection

```

IF fire_status == "DETECTED" OR fire_status == "FIRE" then
    Update GUI status to "ALERT" (RED)
    Display "FIRE DETECTED - EVACUATE" alert
    Trigger fire alarm
    Open all gates for emergency exit
    Log fire emergency event
    Send emergency notifications to authorities
    TRIGGER: Emergency lighting activation (See Lighting Rule 9)
    TRIGGER: Unlock all classroom doors (See Lighting Rule 13)
ELSE
    Update GUI status to "SAFE" (GREEN)
    Continue normal operation
END IF

```

Payment and billing rules

Rule 9: Cost Calculation

IF vehicle is parked then

 base_cost = £10.00 (booking fee)

 extension_cost = extension_hours × £5.00

 parking_cost = parking_hours × £2.00

 total_cost = base_cost + extension_cost + parking_cost

 Update cost display on GUI every minute

 Log cost updates

END IF

Rule 10: Booking Extension

IF user requests extension AND booking is active then

 Add 1 hour to expiration time

 Add £5.00 to total cost

 Update GUI with new expiration time

 Log extension transaction

 Send confirmation to user

ELSE

 Display “Cannot extend booking” error

END IF

3.2 Smart lighting system rules

Classroom scheduling rules

Rule 11: Class Auto-Activation (Linked from Parking)

IF teacher_vehicle_detected_in_parking AND

 class_scheduled_within_30_minutes then

 Pre-activate assigned classroom:

 Unlock classroom door

 Turn on lights (LED1, LED2, LED3, LED4) to 80%

 Start AC at preset temperature (22°C)

 Power on projector standby mode

 Display “Room Ready” on door panel

 Send “Classroom Activated” notification to teacher

 Update lighting dashboard

 Log pre-activation event

END IF

Rule 12: Manual Classroom Activation

IF current_time = (scheduled_class_time - 5 minutes) AND teacher NOT in parking then

 Wait additional 5 minutes

 Send “Class Starting Soon” reminder to teacher

 Keep room in standby mode

 IF teacher arrives then

 Execute Rule 11

 ELSE

 Keep room locked

 Notify students of delay

 END IF

END IF

Rule 13: Class End Auto-Deactivation

```

IF current_time = (scheduled_end_time + 5 minutes) then
  Check motion sensor status
  IF no_motion_detected then
    Start shutdown sequence:
      Turn off projector
      Dim lights to 50% for 2 minutes
      Display "Shutting Down in 2 minutes"
      After 2 minutes:
        Turn off all lights
        Set AC to standby (26°C)
        Lock door
        Update room status to "Available"
  ELSE IF motion_detected then
    Extend session by 15 minutes
    Display "Extended 15 minutes"
    Notify next teacher if room booked
    Log extension event
  END IF
END IF

```

Lighting control rules**Rule 14: Adaptive Lighting Control**

```

IF class_type = "Presentation" then
  Set front lights (LED1, LED2) to 30%
  Set back lights (LED3, LED4) to 50%
  Enable projector mode
ELSE IF class_type = "Examination" then
  Set all lights to 100%
  Disable projector
  Lock lighting controls
ELSE IF class_type = "Lab Work" then
  Set all lights to 80%
  Enable individual zone control
ELSE // Regular class
  Set all lights to 90%
  Enable teacher control panel
END IF

```

Rule 15: Emergency Lighting (Linked from Parking)

```

IF emergency_triggered_from_parking OR fire_detected then
  Switch to emergency power
  Activate emergency lights only
  Unlock all doors immediately
  Display "Emergency" on all panels
  Guide to exits with lighting
  Log emergency activation
END IF

```

Climate control rules

Rule 16: Temperature Management

IF room_temperature > (set_temperature + 2°C) then

 Increase AC cooling power

 IF temperature not dropping after 10 minutes then

 Check for open windows/doors

 Display “Please close windows/doors”

 Send AC malfunction alert

 END IF

ELSE IF room_temperature < (set_temperature - 2°C) then

 Reduce AC cooling

 Optimize for energy saving

END IF

Rule 17: Occupancy-Based Climate

IF occupancy_count > 30 students then

 Decrease set temperature by 1°C

 Increase ventilation rate

ELSE IF occupancy_count < 10 students then

 Increase set temperature by 1°C

 Reduce ventilation to minimum

ELSE IF room_empty for 10 minutes then

 Set AC to standby mode (26°C)

END IF

3.3 Smart trash collection system rules

Bin capacity monitoring rules

Rule 18: Individual Bin Fill Level Detection

IF bin_fill_level >= 80% then

 Set bin_status = “Nearly Full”

 Display yellow LED indicator

 Add bin to collection queue

 IF bin_fill_level >= 90% then

 Set bin_status = “Full”

 Display red LED indicator

 Trigger immediate vacuum collection

 Send alert to dashboard

 END IF

ELSE IF bin_fill_level >= 60% then

 Set bin_status = “Moderate”

 Display green LED indicator

 Monitor every 30 minutes

ELSE

 Set bin_status = “Available”

 Display green LED indicator

 Monitor every hour

END IF

Rule 19: Scheduled Collection Time

IF current_time = scheduled_collection_time then

 FOR each bin IN system

```

    IF bin_fill_level >= 30% then
        Add bin to collection queue
        Set collection_priority based on fill_level
    END IF
END FOR
IF collection_queue NOT empty then
    Start vacuum collection sequence
END IF
END IF

```

Vacuum system operation rules

Rule 20: Vacuum Collection Sequence

```

IF vacuum_collection_triggered then
    Check main_bin capacity
    IF main_bin_fill_level < 80% then
        FOR each bin IN collection_queue
            Set vacuum_status = "ACTIVE"
            Lock all bin lids (safety)
            Open valve for target bin
            Start vacuum motor
            Monitor suction pressure
            IF pressure_normal FOR 30 seconds then
                Close bin valve
                Mark bin as "Emptied"
                Reset bin fill level to 0%
            ELSE IF pressure_low then
                Stop vacuum
                Log "Blockage detected"
                Send maintenance alert
                Break collection cycle
            END IF
            Wait 5 seconds between bins
        END FOR
        Set vacuum_status = "IDLE"
        Unlock all bin lids
    ELSE
        Cancel collection
        Send "Main bin full" alert
    END IF
END IF

```

Rule 21: Main Bin Capacity Management

```

IF main_bin_fill_level >= 85% then
    Set alert_level = "HIGH"
    Send notification: "Main bin nearly full"
    Disable automatic vacuum cycles
ELSE IF main_bin_fill_level >= 95% then
    Set alert_level = "CRITICAL"
    Send urgent notification
    Call manager if no response in 10 minutes
    Lock all individual bins
END IF

```

Ultrasonic sensor rules

Rule 22: Proximity-Based Lid Control

```

IF ultrasonic_sensor_detects_object
  Measure distance to object
  IF distance < 30cm AND vacuum_status = "IDLE" then
    Check bin fill level
    IF bin_fill_level < 95% then
      Open lid smoothly (2 seconds)
      Keep lid open while object detected
    ELSE
      Display "Bin Full" message
      Keep lid closed
    END IF
  ELSE IF vacuum_status = "ACTIVE" then
    Display "System Busy" indicator
    Keep lid locked for safety
  END IF
ELSE IF no_object_detected FOR 5 seconds then
  Close lid smoothly (2 seconds)
END IF

```

3.4 System integration rules

Rule 23: Cross-System Emergency Response

```

IF emergency_detected_in_ANY_system then
  Parking: Open all gates
  Lighting: Activate emergency lights, unlock all doors
  Trash: Stop all operations, unlock bins
  Send unified emergency alert
  Log emergency across all systems
  Activate evacuation protocol
END IF

```

Rule 24: Energy Optimization Integration

```

IF peak_hours (2PM - 5PM) then
  Parking: Dim non-essential lighting
  Lighting: Reduce AC in empty rooms, dim corridors
  Trash: Delay non-critical collections
  Calculate total energy savings
  Display on main dashboard
END IF

```

Rule 25: Maintenance Coordination

```

IF maintenance_required_in_ANY_system then
  Create unified maintenance ticket
  Check for related issues in other systems
  Schedule maintenance window
  Notify affected users
  Coordinate system shutdowns
END IF

```

3.5 Data update rules

Rule 26: Database Synchronization

EVERY 3 seconds:

- Fetch safety data from all systems
- Update unified dashboard
- Check for cross-system triggers
- Log data refresh

END

EVERY 5 seconds:

- Fetch operational data
- Update all GUIs
- Check for expired bookings/sessions
- Execute scheduled tasks

END

Rule 27: Real-time Updates

IF any_system_status_changes then

- Update central database immediately
- Update all affected GUIs
- Trigger related system rules
- Send notifications as needed
- Log all changes with timestamps

END IF

3.6 Priority system

Rule 28: Unified Operation Priority

Priority 1 (HIGHEST): Life safety (fire, gas, emergency)

Priority 2: Security (unauthorized access, breaches)

Priority 3: Normal operations (bookings, classes, collections)

Priority 4: Optimization (energy saving, scheduling)

Priority 5 (LOWEST): Maintenance and updates

IF higher_priority_event_occurs then

- Pause lower priority operations
- Handle emergency first
- Resume normal operations after resolution

END IF

3.7 Implementation summary

Every operation follows this sequence:

1. Check conditions across all systems
2. Update central database
3. Update all relevant GUIs
4. Trigger cross-system actions
5. Log all events with correlation IDs
6. Handle errors gracefully

This integrated system ensures:

- Seamless operation between parking, lighting, and trash systems
- Unified emergency response
- Optimized energy usage across campus
- Coordinated maintenance scheduling
- Real-time status updates on all dashboards

4 THE IMPLEMENTATION OF IoT PROTOTYPES

4.1 System design and interface

The smart parking system diagram is shown in Figure 1.

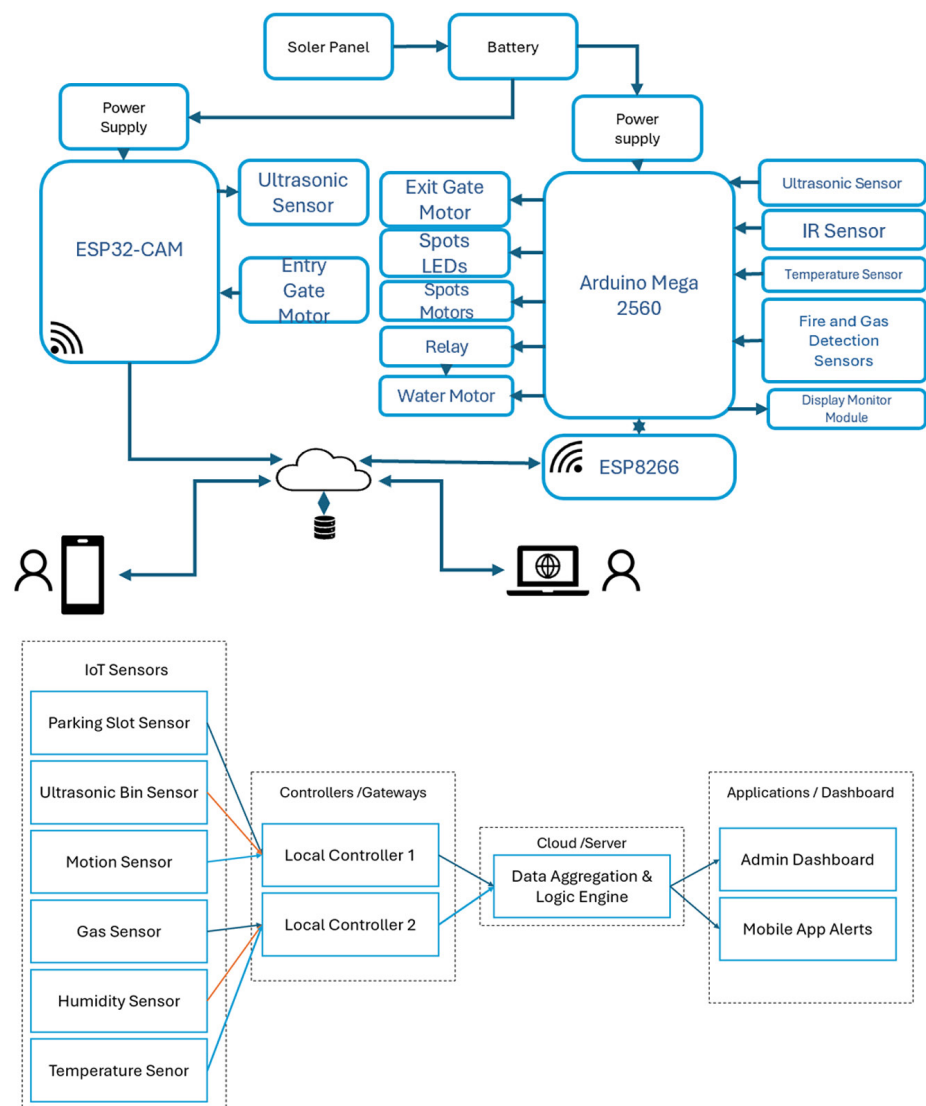


Fig. 1. Smart parking system

A part of the smart parking system flowchart is shown in Figure 2.

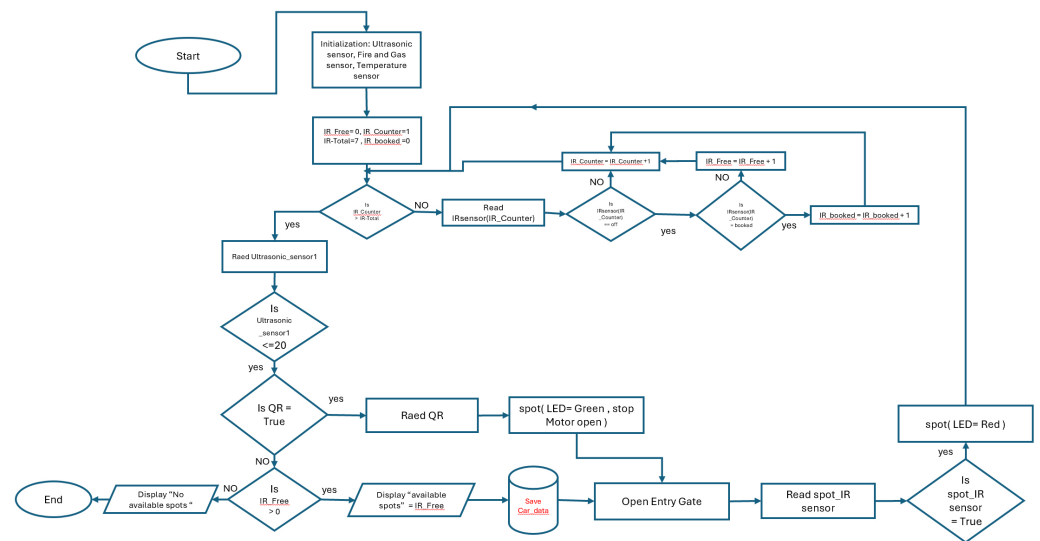


Fig. 2. Smart parking system flowchart

The safety flowchart is shown in Figure 3

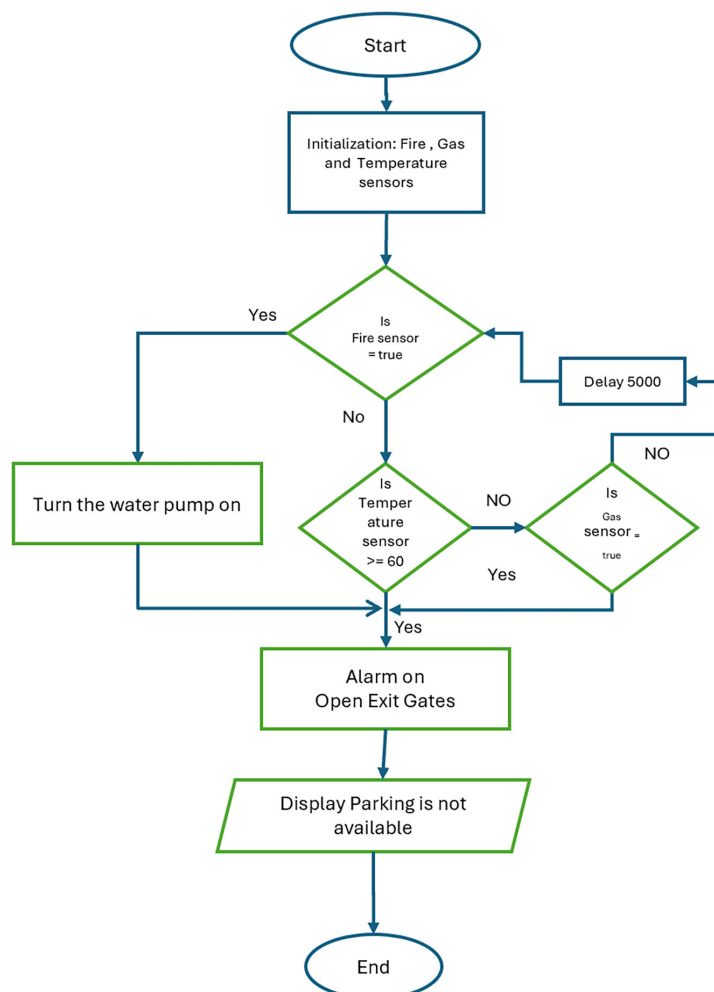


Fig. 3. Safety flowchart

4.2 Manager's system

The main login and homepage interface of the Smart University IoT Management System. It presents a user-friendly login screen and a well-structured homepage that highlights the system's core modules, including Smart Parking, Intelligent Lighting, and Waste Management. The interface is designed for intuitive navigation and quick access to smart campus services. Figure 4 shows the manager's system welcome screen and login page.

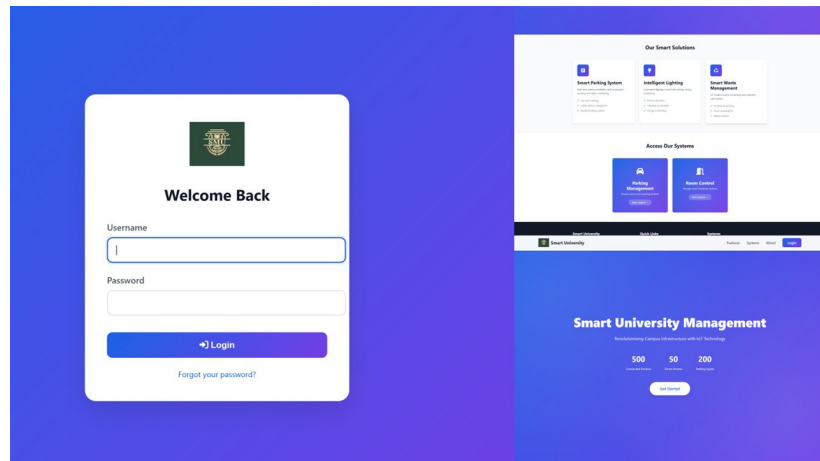


Fig. 4. Manager's system welcome screen and login page

The smart parking system dashboard, smart lighting system dashboard, and smart waste system dashboard are shown in Figures 5, 6, and 7.

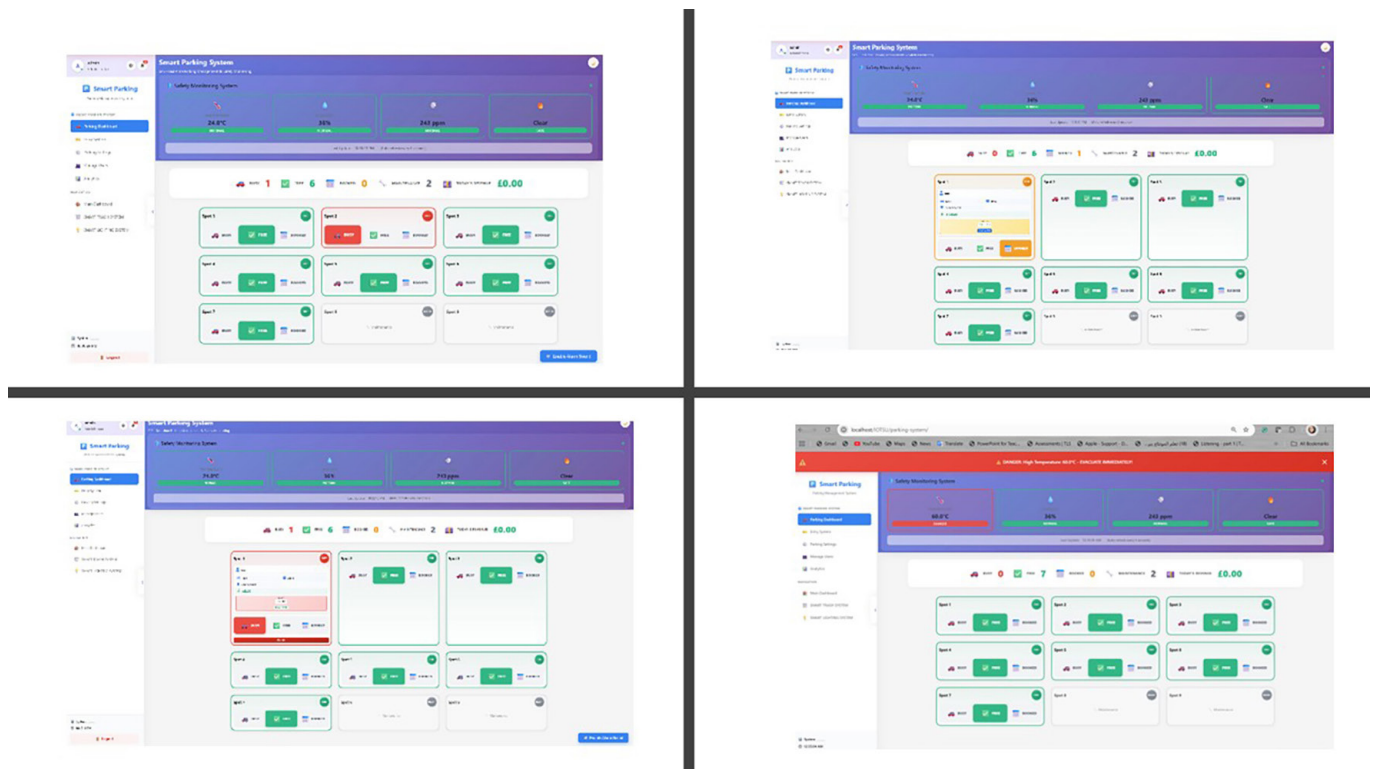


Fig. 5. Manager's smart parking system dashboard

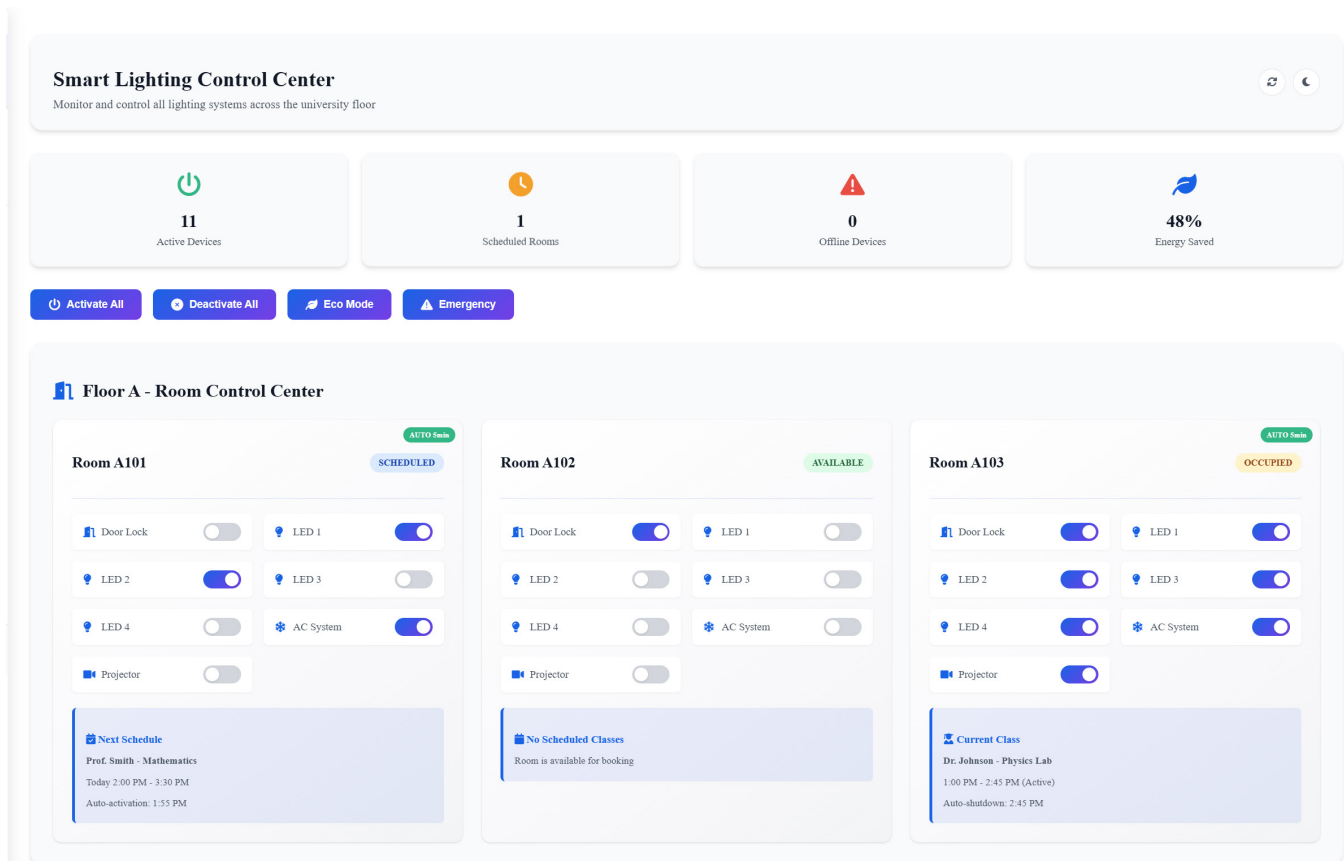


Fig. 6. Manager's smart lighting system dashboard

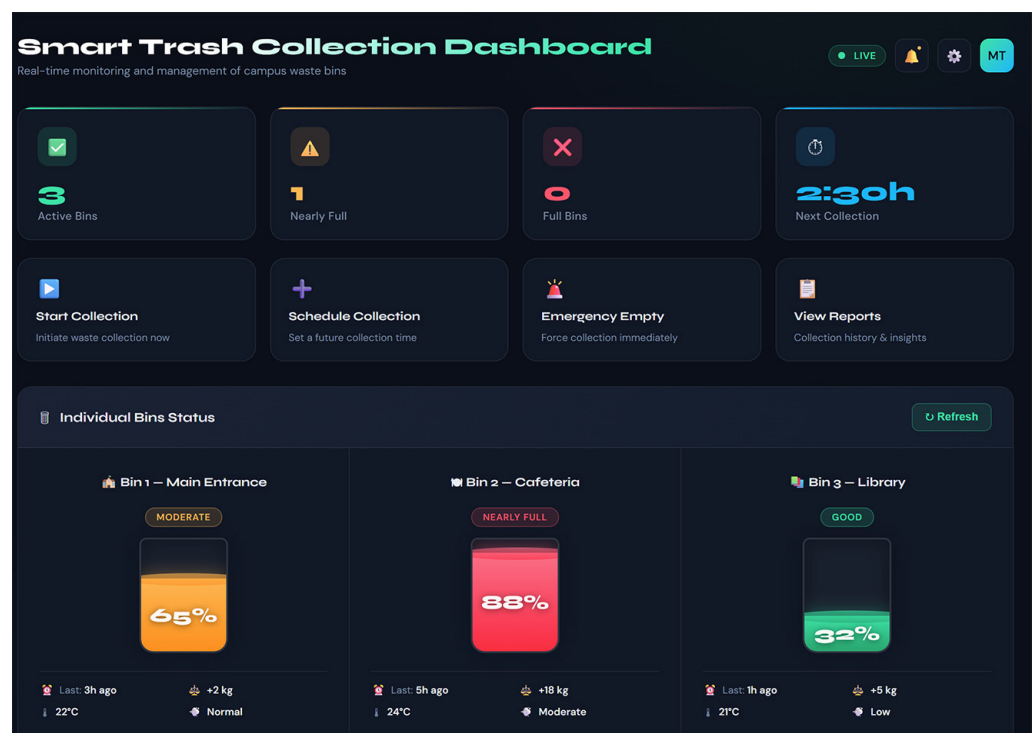


Fig. 7. Manager's Smart Waste system dashboard

4.3 User's system

The main login and homepage interface of the user's system and the application screens are shown in Figures 8 and 9.

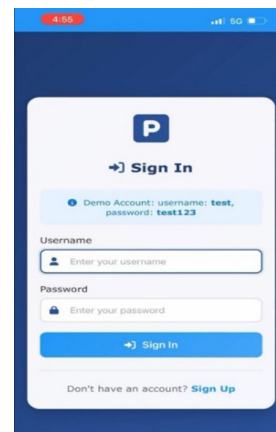


Fig. 8. User's system: Login or Register screen

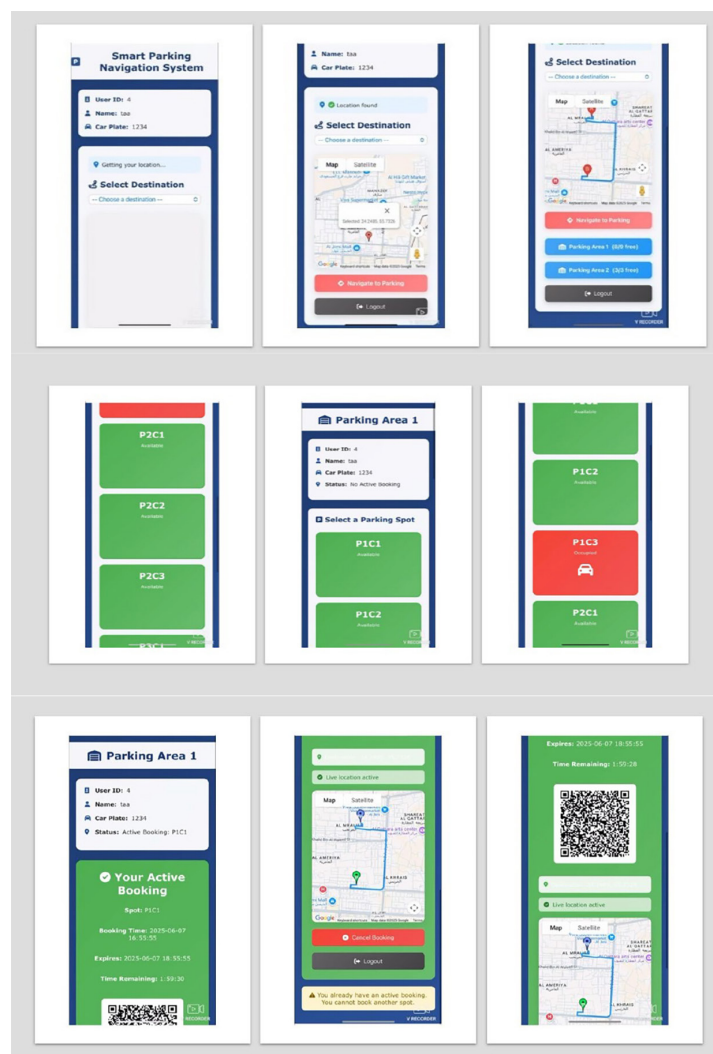


Fig. 9. User's system screens

Examples of test shown in the tables below:

Table 1 shows how parking slot statuses transition based on sensor input and booking status. It includes GUI feedback such as color-coded messages (“FREE,” “BOOKED,” “BUSY”) and gate actions like automatic opening when needed.

Table 1. Parking spot state changes

Current Status	Sensor Detects Vehicle	New Status	Gate Action	GUI Update
FREE	No Vehicle	FREE	Normal	Green “FREE”
FREE	No Vehicle	BOOKED	Normal	Yellow “BOOKED”
FREE	Vehicle	BUSY	Normal	Red “BUSY”
BOOKED	No Vehicle	BOOKED	Normal	Yellow “BOOKED”
BOOKED	Vehicle	BUSY	OPEN	Red “BUSY”
BUSY	Vehicle	BUSY	Normal	Red “BUSY”
BUSY	No Vehicle	FREE	OPEN	Green “FREE”

Table 2 defines the logic for controlling gate behavior based on safety status, QR code validation, and payment status. It includes emergency scenarios (e.g., fire or danger) where both entry and exit gates are forcefully opened to ensure safety.

Table 2. Master gate decision table

Safety Status	QR Valid	Payment Status	Emergency	Entry Gate	Exit Gate	Override
● All Safe	✓ Valid	✓ Paid	✗ None	OPEN	OPEN	Normal
● All Safe	✗ Invalid	✓ Paid	✗ None	CLOSED	OPEN	Normal
● All Safe	✓ Valid	✗ Unpaid	✗ None	OPEN	CLOSED	Normal
● Warning	✓ Valid	✓ Paid	✗ None	OPEN	OPEN	Normal
● Danger	Any	Any	✓ Yes	FORCE OPEN	FORCE OPEN	Emergency
● Fire	Any	Any	✓ Yes	FORCE OPEN	FORCE OPEN	Emergency

Table 3 shows how the system controls the gates during emergency situations like fire, high temperature, gas leaks, manual alerts, and power failure. It also shows the priority level of each emergency, which helps the system decide which situation is more dangerous and should be handled first.

Table 3. Emergency override logic

Emergency Type	Trigger	All Gates Action	Safety System	Display	Priority
Fire Detected	Fire = DETECTED	FORCE OPEN ALL	Fire Alarm ON	“🔥 FIRE - EVACUATE NOW”	1 (Highest)
High Temperature	Temp > 60°C	FORCE OPEN ALL	Alarm ON	“🔥 CRITICAL TEMP - EVACUATE”	2
Critical Gas	Gas > 700ppm	FORCE OPEN ALL	Alarm ON	“☠️ TOXIC GAS - EVACUATE”	3
Manual Emergency	Emergency Button	FORCE OPEN ALL	Alarm ON	“🚨 MANUAL EMERGENCY”	4
Power Failure	No Power	FAIL-SAFE OPEN	Backup Power	“⚡ POWER FAILURE”	5

Table 4 shows the logic for controlling gate behaviour based on QR code validation.

Table 4. Entry gate control

Statue	QR Code Valid	Booking Status	Spot Status	Gate Action	Display Message
1	✓ Valid	Active	Booked/Free	OPEN	"Welcome [User]"
2	✓ Valid/✗ Invalid/ ✗ No QR	Expired/Any	Any	CLOSED	"Booking Expired"/"Invalid QR Code"/"Scan QR Code"
3	✓ Valid	Cancelled	Any	CLOSED	"Booking Cancelled"

5 CONCLUSION

This paper has proposed and implemented an IoT-based Smart Campus System that integrates real-time monitoring, automation, and intelligent control for parking, lighting, and waste management. A key contribution of this work is the incorporation of a structured Knowledge Base (KB) that supports decision-making processes across the system.

The KB played a central role in handling dynamic changes in sensor inputs, parking state transitions, and gate control logic. By storing predefined rules and responses, the system was able to react intelligently to varying scenarios such as vehicle detection, booking status, and emergency situations. This rule-based architecture increases the system's flexibility, scalability, and ease of future modification.

Graphical user interfaces and decision tables were presented to illustrate the system's behavior and validate its functionality. The modular design of the KB allows for continuous expansion, such as integrating AI or machine learning models in the future.

In conclusion, the integration of a knowledge base with IoT enhances not only automation but also the reliability and adaptability of smart campus environments, making it a promising solution for modern educational institutions.

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