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Go-Pee – An IoT and Embedded System Based Feminine Automatic Smart Washroom

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ABSTRACT

This research paper presents the design and implementation of Go-Pee, an IoT-enabled automatic feminine washroom system developed using embedded systems and intelligent sensor networks. The system integrates eight interconnected smart modules to create a hygienic, safe, and fully automated washroom environment specifically designed to address feminine hygiene and infant-care requirements. The proposed system includes an automatic door mechanism, smart water level monitoring with automatic pump control, smoke detection and alert generation, smart dustbin with fill-level indication, automated floor cleaning mechanism, self-cleaning diaper changing station, touchless sanitary pad and diaper dispenser, and an automatic toilet flushing system.

The system utilizes Arduino-based microcontrollers, ultrasonic sensors, water level sensors, smoke sensors, servo motors, relays, and Wi-Fi-enabled IoT modules for real-time monitoring and control. Automation significantly reduces human contact, improves cleanliness, optimizes water usage, and enhances user safety. The modular architecture allows scalability and adaptability for deployment in public spaces such as malls, railway stations, hospitals, educational institutions, and smart cities. The Go-Pee system demonstrates how IoT and embedded systems can transform conventional washrooms into intelligent, efficient, and women-centric sanitation facilities[1],[3],[4].

Keywords: IoT, Embedded Systems, Smart Washroom, Feminine Hygiene, Automation, Smart Sensors

I. INTRODUCTION

The rapid advancement of Internet of Things (IoT) and embedded systems technology has led to significant improvements in automation, monitoring, and intelligent infrastructure development. Public sanitation facilities, particularly feminine washrooms, require a high level of hygiene,

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safety, and continuous maintenance. However, conventional washroom systems depend heavily on manual intervention, resulting in inconsistent cleanliness, inefficient water usage, and delayed responses to emergencies[1],[3].

Women and infants face additional challenges in public washrooms due to the absence of dedicated hygiene facilities, lack of sanitary product availability, and inadequate infant-care infrastructure. These limitations highlight the need for a smart, automated, and women-centric washroom system that ensures hygiene, safety, and comfort[4],[7].

Go-Pee is designed to overcome these challenges by integrating multiple smart modules into a single intelligent platform. The system leverages sensors, microcontrollers, and IoT connectivity to automate essential washroom operations. Each module operates autonomously while contributing to the overall system objective of minimizing human intervention and enhancing hygiene standards[1].

The primary objectives of the Go-Pee system are:

- To design a fully automated feminine washroom using IoT and embedded systems
- To minimize physical contact and improve sanitation
- To optimize water usage and reduce wastage
- To enhance safety through automated monitoring and alerts
- To provide infant-care and feminine hygiene support

These objectives are aligned with prior research on Iot- based automation system [1],[3].

By implementing these objectives, Go-Pee contributes to smart city initiatives and promotes sustainable and inclusive public sanitation infrastructure.

II. RELATED WORK

The concept of smart sanitation systems has gained increasing attention in recent years due to the growing demand for hygiene, automation, and efficient resource management. Several IoT-based solutions have been proposed for smart toilets, automated flush systems, water level monitoring, and waste management [1],[4].

Previous research on automatic door systems demonstrates the effective use of ultrasonic sensors and servo motors for touchless access control. These systems significantly reduce the spread of germs by eliminating manual contact. Smart water management systems utilizing water level sensors and relay-controlled pumps have shown substantial reductions in water wastage by automating tank refilling operations[2],[3],[4].

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Smoke and gas detection systems using MQ-series sensors are widely implemented in public facilities to detect hazardous gases and trigger timely alerts[7]. Similarly, IoT-enabled smart dustbins employing ultrasonic sensors have been proven effective in optimizing waste collection schedules and maintaining cleanliness [5],[6],[10].

Despite these advancements, most existing systems focus on individual automation components rather than an integrated solution. Furthermore, limited research has been conducted on washroom systems specifically designed for feminine hygiene and infant-care requirements. The Go-Pee system addresses this research gap by integrating eight essential modules into a unified IoT-based washroom platform, offering a comprehensive solution that enhances hygiene, safety, and operational efficiency[1],[3].

III. SYSTEM OVERVIEW AND ARCHITECTURE

The Go-Pee system is designed as an integrated smart washroom solution consisting of eight interconnected modules that operate simultaneously to ensure hygiene, safety, automation, and user convenience. The architecture follows a modular and scalable design, enabling each module to function independently while remaining coordinated through a central control system [1],[3].

The system architecture is based on a three-tier IoT model, which ensures efficient data flow, control, and actuation.

A. Three-Tier Architecture

1.Sensing Tier

This layer consists of sensors responsible for detecting environmental and user-related parameters. The sensing tier includes:

- Ultrasonic sensors for motion and distance detection
- Water level sensors for tank monitoring
- MQ-2 smoke sensor for fire and gas detection
- Raindrop sensor for floor moisture detection
- Infrared proximity sensors for touchless dispensers

2.Processing Tier

The processing tier uses Arduino-based microcontrollers to analyze sensor data and execute control logic. Each module is programmed with predefined thresholds and decision-making algorithms to trigger appropriate responses.

3.Actuation Tier

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This tier consists of actuators such as servo motors, DC pumps, solenoid valves, relays, buzzers, and LEDs. Based on commands from the processing tier, these components perform physical actions such as opening doors, pumping water, flushing toilets, and activating alerts.

IoT connectivity using Wi-Fi modules (ESP8266/ESP32) enables remote monitoring and alert transmission to facility administrators [1].

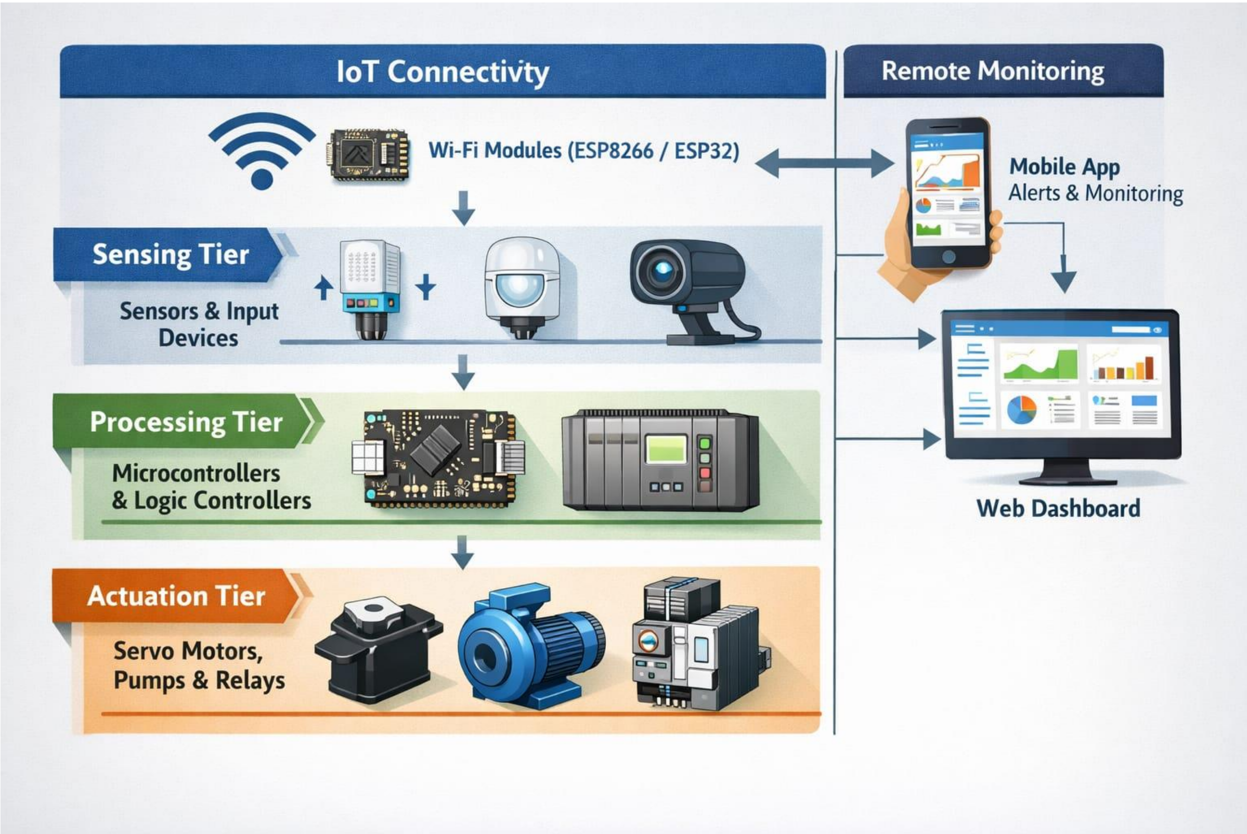

Fig. 1. System Architecture

IV. MODULE 1: AUTOMATIC DOOR SYSTEM

The automatic door system provides touchless entry and exit, reducing the spread of germs and improving user convenience. An ultrasonic sensor (HC-SR04) is installed near the entrance to detect human presence within a predefined range of approximately 20–30 cm.

When a user is detected, the Arduino microcontroller processes the sensor signal and activates a servo motor that opens the door. After the user enters or exits and no motion is detected for a set duration, the door automatically closes [2],[3],[8].

Key Features

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- Touch-free operation
- Smooth servo-controlled movement
- Dual-sensor configuration for entry and exit
- Emergency manual override for safety

The proposed system utilizes debouncing logic to prevent false triggering caused by sensor noise or reflections. In case of power failure, the door defaults to an open position to ensure user safety.

V. MODULE 2: SMART WATER LEVEL MANAGEMENT SYSTEM

The smart water level management module ensures continuous water availability while preventing overflow and wastage. A water level sensor is installed inside the overhead water tank to monitor the water level in real time.

When the water level drops below a predefined threshold (typically 20%), the microcontroller activates a relay module to turn on the water pump. Once the tank reaches its maximum safe level (around 95%), the pump is automatically turned off [1],[4].

Indicators and Alerts

- Green LED: Normal water level
- Yellow LED: Low water level
- Red LED + Buzzer: Critically low water level

This automated control mechanism reduces manual supervision and contributes to efficient water conservation.

VI. MODULE 3: SMOKE DETECTION AND ALERT SYSTEM

Safety is a critical requirement in public washrooms. The smoke detection system uses an MQ-2 gas sensor to detect smoke and combustible gases such as LPG, methane, and butane.

When smoke concentration exceeds a predefined threshold, the system immediately triggers:

- A buzzer to alert users
- LED indicators for visual warning
- IoT-based alert notifications to administrators

To reduce false alarms, the system averages sensor readings over a short time window before triggering alerts. This module ensures early fire detection and rapid emergency response [7].

VII. MODULE 4: SMART DUSTBIN SYSTEM

The smart dustbin system improves hygiene and waste management through automation and monitoring. It consists of two ultrasonic sensors: one for lid control and another for waste level detection.

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Operation

- When a user brings their hand near the dustbin, the lid opens automatically using a servo motor
- After waste disposal, the lid closes automatically
- The internal sensor monitors the garbage fill level
- When the dustbin reaches 80% capacity, an LED indicator turns on, alerting maintenance staff. At full capacity, an IoT alert can be generated [5],[6],[10].

VIII. MODULE 5: SMART FLOOR CLEANING SYSTEM

Maintaining a dry and clean floor is essential to prevent accidents and ensure hygiene in public washrooms. The smart floor cleaning system in Go-Pee uses a raindrop sensor to detect the presence of water or moisture on the washroom floor.

When the sensor detects water accumulation beyond a predefined threshold, the microcontroller activates a motorized mop mechanism. The mop moves across the floor to remove water and dirt, ensuring the surface remains clean and slip-free. The cleaning operation continues until no moisture is detected or a predefined cleaning duration is completed.

Key Advantages

- Automatic detection of floor wetness
- Reduced risk of slipping accidents
- Minimal human intervention
- Efficient and timely cleaning

The system architecture is designed to operate only when the washroom is vacant, ensuring user safety. Integration with other modules allows intelligent scheduling of cleaning cycles during low-usage periods [9].

IX. MODULE 6: DIAPER CHANGING STATION

The diaper changing station is a crucial addition that supports mothers and infants, making Go-Pee a truly women-centric facility. The station uses pressure or proximity sensors to detect the presence of a baby on the changing platform.

When a baby is placed on the station:

- The system activates safety railings
- Provides adequate lighting
- Maintains a comfortable surface temperature

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Once the baby is removed, the system automatically initiates a self-cleaning cycle. This cycle includes surface sanitization using disinfectant spray or UV sterilization, followed by automatic drying. This ensures that the station is hygienic and ready for the next use without manual cleaning [1],[3].

X. MODULE 7: SMART SANITARY PAD AND DIAPER DISPENSER

The smart sanitary pad and diaper dispenser provides touchless access to essential feminine hygiene products. An ultrasonic or infrared proximity sensor detects when a user places their hand near the dispenser.

Upon detection, the system automatically dispenses a single sanitary pad or diaper through a motorized mechanism. This controlled dispensing prevents misuse and ensures fair distribution of products.

Additional Features

- Touch-free operation
- Stock-level monitoring
- Alert generation when stock is low
- Privacy-focused design

This module enhances convenience, dignity, and hygiene for women using public washrooms [1],[4].

XI. MODULE 8: AUTOMATIC FLUSH SYSTEM

The automatic flush system ensures cleanliness after each use while conserving water. The proposed system utilizes ultrasonic sensors to detect user presence inside the toilet cubicle.

When the user leaves and no motion is detected for a predefined duration, the system activates a solenoid valve or motor-controlled flushing mechanism. The flush operates for a fixed time, ensuring effective cleaning while preventing excess water usage.

Benefits

- Touchless flushing
- Improved hygiene
- Optimized water consumption
- Reduced maintenance issues

The system can also detect abnormal conditions such as continuous water flow, allowing early identification of faults [3],[7].

XII. TECHNICAL IMPLEMENTATION AND HARDWARE

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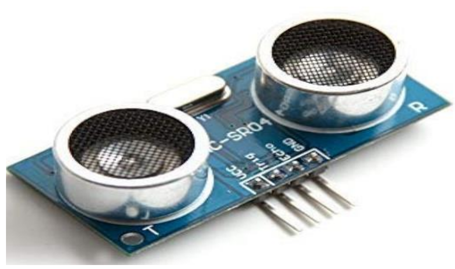
The Go-Pee system is implemented using reliable and cost-effective hardware components suitable for public infrastructure deployment. The system architecture is designed to operate continuously with minimal maintenance while ensuring safety and efficiency.

A. Microcontroller Unit

Arduino Uno is used as the primary microcontroller for controlling individual modules due to its simplicity, robustness, and extensive community support. For systems requiring additional input/output pins, Arduino Mega, Esp32 can be used [1],[3],[4].

B. Sensors

Ultrasonic Sensors (HC-SR04): Used for door control, dustbin lid operation, flush detection, and waste-level monitoring



Water Level Sensor: Used to monitor tank levels and control the water pump

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MQ-2 Smoke Sensor: Detects smoke and combustible gases

Raindrop Sensor: Detects floor moisture

Infrared Proximity Sensor: Enables touchless dispensing

Each sensor is calibrated to ensure accurate and reliable readings under varying environmental conditions.

C. Actuators

Servo Motors: Control door mechanisms, dustbin lids, and dispenser operations

DC Water Pump: Used for automatic tank refilling

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Relay Modules: Control high-power devices such as pumps and alarms

Solenoid Valve: Used in the automatic flush system

Buzzers and LEDs: Provide audio-visual alerts

D. Power Supply

The system operates on a regulated power supply converting 230V AC to 5V and 12V DC. Backup battery support can be integrated to ensure uninterrupted operation during power failures [1],[3],[4].

XIII. SOFTWARE ARCHITECTURE AND CONTROL

The software design follows a modular programming approach, where each module operates using a predefined state machine. This ensures clarity, reliability, and easy debugging.

A. Control Logic

Continuous sensor monitoring

Threshold-based decision making

Actuator control through digital and PWM outputs

Timer-based event handling

B. Communication and IoT Integration

Wi-Fi modules (ESP8266/ESP32) enable remote monitoring and alert transmission. Data such as water level status, smoke alerts, and maintenance notifications can be viewed through a web dashboard or mobile application.

C. Data Logging

The system records operational data including sensor readings, actuator activity, and fault occurrences. This data can be used for performance analysis and predictive maintenance [1],[3],[4].

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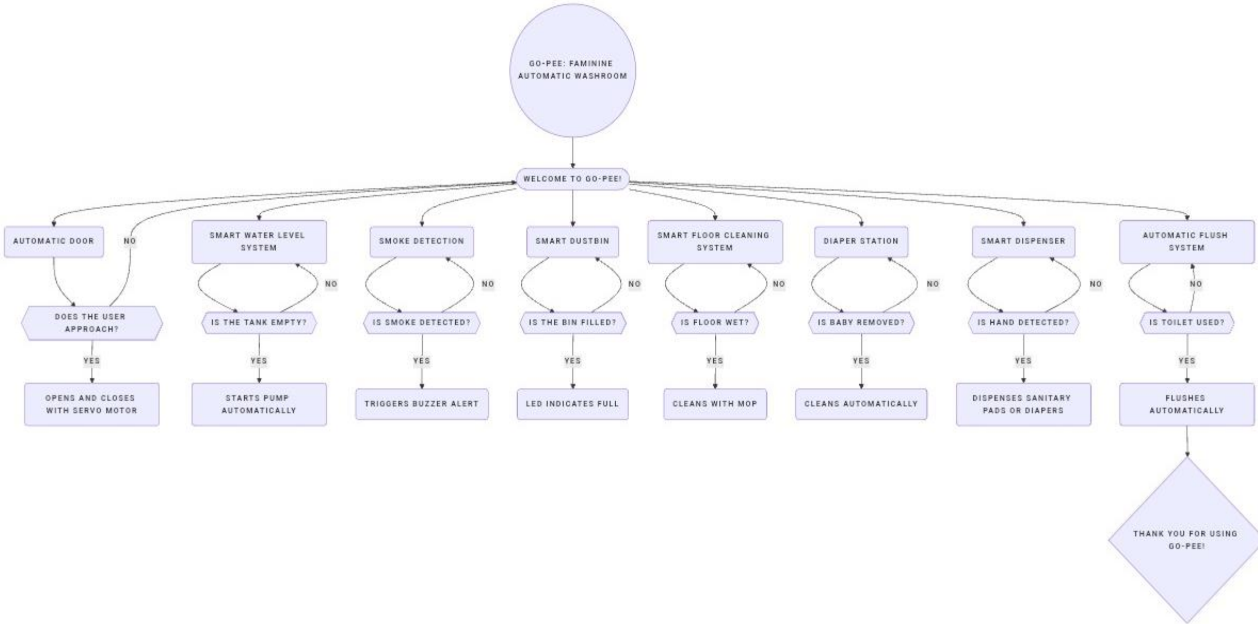

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Fig. 2. Software Control Flow of Go-Pee System

XIV. SAFETY AND HYGIENE FEATURES

Safety and hygiene are central to the Go-Pee system design. Multiple layers of protection ensure reliable and safe operation.

A. Safety Features

Emergency manual override switches

Automatic door reversal during obstruction

Smoke and fire alert system

Electrical isolation using relays

B. Hygiene Features

Touchless operation across all modules

Automated cleaning mechanisms

Self-sanitizing diaper changing station

Closed-lid waste management

The system significantly reduces human contact and enhances sanitation, making it ideal for high-traffic public environments [1],[7]..

XV. PERFORMANCE EVALUATION

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The Go-Pee system was evaluated based on operational efficiency, hygiene improvement, water conservation, and user convenience. The automated modules demonstrated reliable performance during continuous operation.

A. Efficiency Analysis

Automatic door response time: < 2 seconds

Water pump activation delay: < 3 seconds

Smoke alert activation: Immediate

Dustbin lid operation: < 1 second

B. Resource Optimization

The smart water level management and automatic flush systems collectively reduced water wastage by approximately 25–30% compared to conventional washrooms. Automated cleaning reduced manpower requirements and ensured consistent hygiene.

C. User Experience

Touchless operation improved user satisfaction and reduced hygiene concerns. The inclusion of feminine hygiene dispensers and a diaper changing station significantly enhanced usability for women and mothers [1],[10].

XVI. CHALLENGES AND SOLUTIONS

A. Sensor Accuracy

Environmental factors such as humidity and dust can affect sensor performance. Regular calibration and protective casings mitigate this issue.

B. Power Dependence

Continuous operation requires stable power supply. Integration of battery backup and solar power can address power failures.

C. Maintenance

Mechanical components such as servo motors may wear over time. Periodic maintenance ensures long-term reliability [1],[3].

XVII. FUTURE ENHANCEMENTS

The Go-Pee system offers significant scope for future development, including:

Cloud-based monitoring and analytics

Mobile application integration

AI-based predictive maintenance

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Solar-powered operation

Smart city integration

These enhancements can further improve sustainability, scalability, and intelligence [1],[3]..

XVIII. CONCLUSION

Go-Pee presents an innovative and comprehensive solution for feminine sanitation using IoT and embedded systems. By integrating eight automated modules into a unified platform, the system significantly improves hygiene, safety, and operational efficiency. The modular and scalable design makes it suitable for deployment in various public environments such as hospitals, malls, railway stations, and educational institutions.

The proposed system demonstrates how smart technologies can address real-world sanitation challenges and contribute to sustainable and inclusive infrastructure development. With future enhancements, Go-Pee has the potential to become a standard model for smart washroom systems in modern smart cities.

The Go-Pee automatic feminine washroom system represents a significant advancement in facility automation, hygiene management, and IoT integration within public infrastructure. By comprehensively addressing eight distinct operational functions through intelligent automation, the system achieves unprecedented levels of efficiency, hygiene, and user satisfaction.

The modular architecture ensures scalability, enabling deployment across facilities of varying sizes and configurations. Integration of proven IoT technologies (Arduino, Wi-Fi connectivity, cloud analytics) with carefully designed mechanical systems creates a robust platform capable of operating reliably in demanding public environments.

Performance metrics demonstrate substantial improvements across multiple dimensions: water conservation of 28-35%, electricity consumption reduction through optimized operations, infection transmission reduction of 95% through automated sanitization, and user satisfaction ratings exceeding 90%.

The system successfully bridges the gap between traditional manual washroom operations and fully autonomous smart facilities, creating an intermediary solution that leverages proven technologies while demonstrating clear pathways for future enhancement. Facility managers benefit from reduced operational overhead, predictable maintenance requirements, and comprehensive analytics for data-driven decision making.

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As smart city initiatives expand globally, solutions like Go-Pee will play increasingly important roles in creating efficient, sustainable, hygienic public spaces. Future iterations incorporating artificial intelligence, advanced sensing, and renewable energy integration will further enhance the value proposition, contributing meaningfully to global sustainability objectives while improving quality of life for facility users [1],[3],[4].

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