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■ RESEARCH ARTICLE

IoT - SMART Urinal cum Disinfectant Flush System

Bhupen Sai Bandi

FIITJEE Junior College, Andhra Pradesh - 520010, India; regelelumii4@gmail.com
Mentor: Bhaskar Bandi, B.E (ECE)

ABSTRACT: This paper endeavours to tackle the challenges of poor sanitation and water conservation in public toilets. Inspired by real-world experiences and the critical need to enhance sanitation while conserving essential resources—such as water, human resources, cleaning materials, and time—an IoT device has been conceptualized. The proposed solution is a 'Microcontroller-Based SMART Urinal cum Disinfectant Flush System,' which operates similarly to a sensor-based urinal and also offers automatic cleaning. Moreover, its smartness allows extensive possibilities for further enhancement. It uses microcontrollers (ESP2866, ESP32), Time of Flight (ToF) sensors, Latching Solenoids, Solenoid Drivers, a DC motor, a water flow sensor, a sound recording cum player, and a speaker. The ESP2866 microcontroller continuously measures distance via a ToF sensor installed at the urinal. Suppose a person remains within proximity to the urinal for over 5 seconds. In that case, it triggers the microcontroller to confirm the person's presence and initiate water flushing for a specific duration after leaving. In addition, if the ESP2866 microcontroller detects the presence of any person, it triggers playing customized announcements. Simultaneously, the ESP32 microcontroller oversees water flow using a water flow sensor. If water flow exceeds a specified duration, the ESP32 microcontroller activates a buzzer to indicate potential water leakage. Programmed timings enable the ESP32 to control the central water supply solenoid, turning it OFF, and the ESP2866 activates the urinal flush solenoid and the DC motor submerged in disinfectant flushes disinfectant in the urinal for a set period. After disinfectant flushing, the ESP32 turns ON the central solenoid to restore the main water supply. At the same time, the ESP2866 deactivates the Urinal Flush Solenoid to halt water flow in the urinal and starts performing the routine. The flushing cycle can be changed from post-urination to pre- & post-urination, and it can be customized. Parameters such as the person-sensing distance, water flow duration, disinfectant flushing time and duration, etc, are customizable. The functionality of automated Urinal Flush, Disinfectant Flush, and a customized announcement system were tested using the designed embedded electronic IoT device. Arduino IDE was used to program Microcontrollers ESP32 and ESP2866.

KEYWORDS: Engineering Mechanics, Internet of Things; Smart Urinal; Disinfectant Flush, Microcontroller.

■ Introduction

The idea of developing a solution to improve sanitation, hygiene, and water conservation in Public Toilets has come to mind after observing/experiencing poor sanitation and hygiene in several public toilets in various places and cities. The following are a few sample photos (Figure A, Figure B, Figure C, Figure D) of the toilets observed.

Figure A: unhygienic surroundings of Public Toilet

Figure B: unhygienic condition of Urinals

Figure C: unhygienic condition of Urinal

Figure D: unhygienic surroundings of Public Toilet

The Honorable Prime Minister of India, Sri. Naredra Modi Ji launched the Swachh Bharat Mission on 2nd October 2014 to achieve universal sanitation coverage and to put the focus on sanitation, "open-defecation free" (ODF), by 2 October 2019. This has improved sanitation conditions very significantly across all parts of India. However, to make these great efforts sustainable and successful, adopting the latest technologies - Embedded Electronics, Information & Communication Technology; easing the operations, maintenance, and supervision of Public Toilets.

The availability of clean and hygienic toilets is a citizen's fundamental right. However, India's growing urbanization, vast geographical area, prevailing systems, and practices made it an enormous task for Urban Local Bodies to provide hygienic public toilets and maintenance.

Hygiene maintenance is essential in public toilets (Viz.: Schools, Educational Institutions, Hospitals, Hotels, Theatres, Malls, Cities, etc.) to overcome the spread of Covid-19 like a pandemic. Public Toilets are one of the vulnerable places for spread of deceases. The physical touch of taps and faucets increases the spread of harmful bacteria.

Still, people are scared of using public toilets because of poor hygiene and foul smell/odor, causing people to prefer to urinate openly. This is due to poor maintenance, poor supervision, and bad usage of toilets by the public.

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Drawbacks of existing traditional Urinals:

1. Manual operation of the valve/faucet, requiring physical touch, posing hygiene concerns.
2. Reluctance to engage with the valve post-urination, leading to incomplete or absent flushing.
3. Necessity for more frequent cleaning of the urinal basin, demanding increased human resources.
4. Unpleasant odors due to inadequate flushing.
5. Potential water wastage caused by valve malfunctions.
6. No mechanism for remote monitoring and supervision..

Drawbacks of existing Sensor based Automatic Urinals:

1. Fixed flush duration without manageability.
2. Predefined time for flush activation, typically occurring 5 to 10 seconds after a person leaves.
3. Lack of control over the triggering distance for the flush mechanism.
4. Absence of a disinfectant flushing system to maintain cleanliness in the urinal basin.
5. Increased maintenance requirements for battery-operated systems, particularly challenging when managing multiple Sensor-based Urinals, demanding more supervision.
6. Inability to monitor water consumption or detect leakages.
7. Absence of mechanisms for monitoring usage analytics & remote supervision of toilets.

After exploring various contemporary solutions for automated urinal flush systems, it was found that none addresses all the essential aspects. To overcome these limitations, devised an IoT (Internet of Things) based Smart Urinal cum Disinfectant flush system aimed at addressing the constraints above. This system serves as a foundational step towards developing a more comprehensive solution.

Description of the project:

IoT (Internet of Things) – Smart Urinal cum Disinfectant Flush System (Figure E) consists of three parts and are:

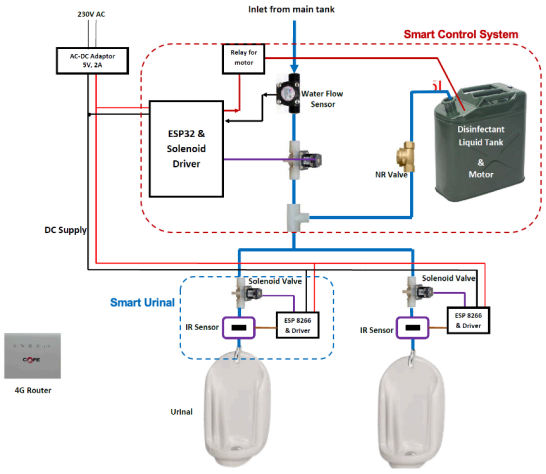

Figure E: Block diagram of loT based Smart Urinal cum Disinfectant Flush

a. Smart Urinal.
b. Smart Control System.
c. 4G Wi-Fi Hotspot.

Software:

Arduino IDE is used for programming the Microcontrollers in this project.

Working:

Flow chart of Smart Urinal cum disinfectant flush system:

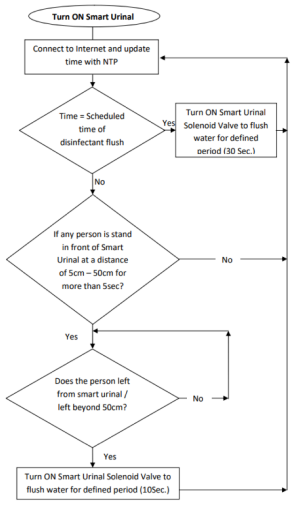

Figure F

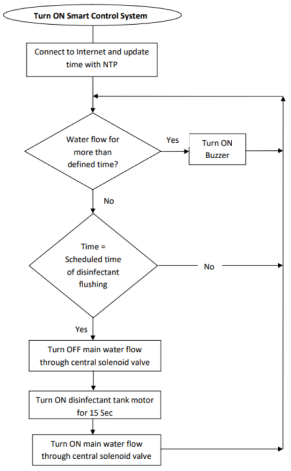

Figure F

a. Smart Urinal:

It is designed using **microcontroller ESP2866, L9110S** – Dual Channel H-Bridge motor driver (as solenoid driver), TOF Sensor –VL5310X, Sound Recorder – ISD 1820, Speaker 0.5W, Latching Solenoid valve. The functioning of the Smart Urinal is explained with a flow chart in Figure F.

1. It establishes an internet connection via a 4G Wi-Fi hotspot and synchronizes its time from an NTP server.
2. It automatically detects a person within a defined proximity for a specified period and initiates water flushing after the person urinates and leaves. In this project, the activation range is set between 5 cm to 50 cm, and the minimum set duration is 5 seconds. If a person enters and exits the proximity in less than 5 seconds within the range of 5 cm to 50 cm, the system will not activate the flush. These parameters are adjustable based on requirements.
3. The flush duration can be customized and it is set as 10 Sec. in this project.
4. As soon as sensor detects a person within specified distance, it plays customised audio. In this project, the announcement is – **"This is an automatic urinal flush system. Please urinate in the urinal only".** It can be modified as you wish.
5. Distance of activation can be modified through the web page.

b. Smart Control System:

It is designed using **microcontroller ESP32, L9110S – Dual Channel H-Bridge motor driver (as solenoid driver), Buzzer, Single Channel Relay, 5V water motor pump, Latching Solenoid valve, tank for disinfectant liquid storage, Non-return Valve, Water Flow Sensor - YF-S201.**

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The functions of the Smart Control System are explained with a flow chart in Figure G. It performs flushing of disinfectant, Water Leakage detection, and alerting.

1. When the Smart Control System is turned ON, it connects to the internet through a 4G Wi-Fi hotspot and updates its time from the NTP server.
2. When the Smart Control System is turned ON, it connects to the internet through a 4G Wi-Fi hotspot and updates its time from the NTP server.
3. As per the desired schedule, the central water supply solenoid will stop the main water supply, and then the disinfectant motor will be turned ON for a programmed period (for 15 Sec in this project).
4. The disinfectant liquid will be sent into the main water pipeline through a non-return valve, as shown in Figure E.
5. After 15 Sec. the central water supply solenoid will start the flow of water from the main water line.
6. It is programmed to turn ON the Smart Urinal's solenoid valve at the same scheduled time for disinfectant flushing. So that as soon as the main water supply is turned OFF by the Smart Control System, Smart Urinal's solenoid will be continued to be in open for 30 Sec.
7. First, for 15 seconds, the disinfectant will be flushed, and for the next 15 seconds, the water will be flushed. This cleanses the urinal with disinfectant. All the parameters are programmable. After the 30 seconds, Smart Urinal's solenoid valve will be closed automatically.
8. ESP 32 microcontroller continuously receives the water flow rate from the water flow sensor. If the water flows continuously for more than a specified period, it will alert through Buzzer. In this project, 0.5 liters/minute is taken as minimum usage, and the period is taken as 120 seconds. If the use is more than 0.5 liters continuously for more than 120 Sec., it will alert through Buzzer.

c. 4G Wi-Fi hotspot:

It is used for Internet connectivity. Smart Control System and Smart Urinal will work synchronously with the clock synchronized with NTP Server.

Advantages:

1. Improved sanitation and hygiene. Water will be flushed automatically after urination.
2. Water will be conserved. Water will be flushed as programmed.
3. Touchless. No spreading of bacteria/virus through the touch of taps/faucets.
4. Flushing of Disinfectants reduces the frequency of manual cleaning of Urinals.
5. Water leakages can be detected. As a result, water loss can be prevented.
6. All the parameters – Distance of activation, Flush time duration, water leakage rate, Disinfectant, etc. can be programmed.
7. Foul smell/odor can be reduced significantly.
8. Human resources for cleaning can be minimized.
9. The cost of maintenance will be minimized.
10. Much public money can be saved through transparency.

Results:

a.

i. Automatic Urinal Flush is working fine per the programmed parameters, distance of activation, and the time period of flushing.

ii. The minimum time to activate (5 Sec has been set as the minimum time to enable flushing. If the user doesn't stay 5 Sec., Flusher will not activate)

iii. Tested modification of the distance of activation through the web page.

b. Disinfectant Flush is working well as per the programmed parameters (Disinfectant flush period).

c. Tested Water Leakage detection alert.

d. Tested customized announcement from Urinal Flushing System.

Conclusion

The IoT - Based SMART Urinal cum Disinfectant Flush System is better than the contemporary Urinal Flush Systems/ solutions. It is more manageable and can be customized. It has a disinfectant flush system, differentiating it from any other available solutions. It has tremendous scope for the market in Urban Local Bodies, Universities, Educational Institutions, Hospitals, Hotels, etc. It reduces manual scavenging work. It can be further developed into a more comprehensive solution suitable for smart cities using Artificial Intelligence.

Scope for improvement:

This project holds significant potential for further development, utility enhancement, and market expansion with the adaption of latest technologies Artificial Intelligence, Data Analytics. Few of them are:

a. Development of a "Data Acquisition, Monitoring & Analytics System – Cloud/Centralized Server" offering the following capabilities:

i. Tracking water consumption on a daily/monthly basis.

ii. Analyzing Smart Urinal Usage Patterns to identify faulty or problematic urinals, simplifying maintenance and planning. Real-time online monitoring of all smart toilets across various geographical scales— individual, street, city, state, country.

b. Development of a Dashboard for centralized monitoring of all the public toilets accessible via a mobile application. This system will monitor Water and Disinfectant levels and the number of flushes per urinal.

c. Integration of provisions for urine sample analysis, potentially alerting individuals using an Ammonia Sensor. For instance, individuals consuming insufficient water could receive alerts prompting them to increase water intake.

d. Monitoring of battery levels remotely and alerting in case of low battery. Utilization of Solar power.

e. Automated sanitizer spraying in toilets and automatic filling of water tanks in Public Toilets.

f. Miniaturization of the device for increased efficiency and practicality.

Prototype Circuit:

Smart Urinal Circuit:

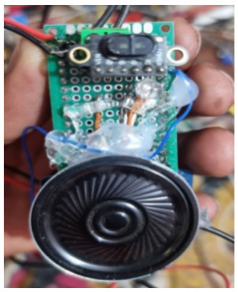

Figure H: Back View

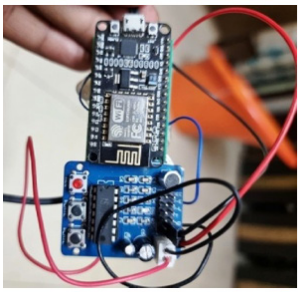

Figure I: Back View

Smart Control System:

Disinfectant Flushing, Water Detection & Water Leakage Alert Board

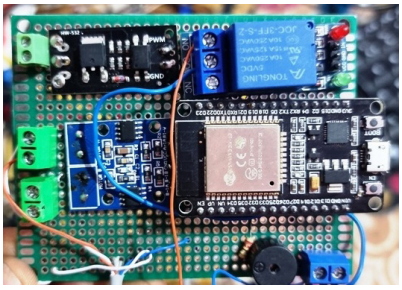

Figure J

Modification of Distance of Operation through Web Page:

Inputted 50cm through the web page, and the result is in Arduino IDE:

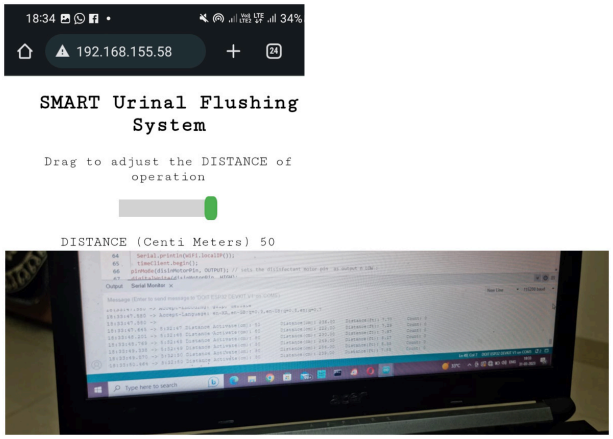

Figure K

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Author

The author of the research paper, Bhupen Sai Bandi, is currently a student at FIITJEE Junior College, Vijayawada, India. He is very much interested in Computer Science Engineering and hopes to pursue higher education in this field. He aimed to combine Computer Science and Electronics engineering to provide the most effective solutions for the betterment and sustainable life worldwide.

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