NATIONAL ENGITECH DIGEST

VOL. 1 ISSUE 1

e-ISSN: 3030-5969

Smart Motion Urinal Flush (SMUF)

Divind Raj Mohan, Iskandar Zulqarnain Nor Azmi, Mohamad Imran Abd Radzi, Aminah Bibi Bawamohiddin
Jabatan Teknologi Maklumat dan Komunikasi, Politeknik Ungku Omar, Jalan Raja Musa Mahadi, 31400 Ipoh, Perak.
divindraj63@gmail.com

Abstract:

Traditional manual urinal flush systems contribute to water waste and pose potential hygiene risks due to user contact. This study aimed to develop a cost-effective and user-friendly automatic urinal flush system. Manual urinal flush systems can lead to excessive water usage and pose hygiene challenges due to the need for direct contact. Current automatic systems are often complex and expensive. This project aimed to design, develop, and test a novel Smart Motion Urinal Flush (SMUF) system that utilizes an ultrasonic sensor to trigger automatic flushing upon user presence, minimize water consumption and enhance hygiene. The project followed a structured methodology encompassing requirement specification, prototyping, and testing phases. Functional and non-functional requirements were established to guide the development process. Multiple prototypes were constructed and underwent rigorous testing to evaluate functionality, user experience, and performance. The SMUF system successfully demonstrated automatic flushing upon user detection, significantly reducing potential water waste compared to manual systems. The user interface, employing two LEDs for clear visual cues, proved to be user-friendly and intuitive. Future iterations could explore alternative power sources or improved battery efficiency to reduce reliance on disposable batteries. Additionally, developing a universally adaptable sensor for varying flushing durations would broaden the system's applicability to toilets alongside urinals.

Keywords: Automatic urinal flush, water conservation, hygiene, sensor-based system.

Introduction

The COVID-19 pandemic has significantly heightened the need for enhanced hygiene and social distancing practices, particularly in public spaces like restrooms. Manual flush systems in these settings pose a potential transmission risk due to the necessity of physical contact (Michael et al., 2022). The SMUF project emerges as a proactive response to this concern, aiming to develop an automatic urinal flush device utilizing ultrasonic motion-detecting technology. This touchless system presents a viable solution to minimize direct physical contact and consequently mitigate the risk of virus transmission during restroom use (Lopes et al., 2024).

The ongoing pandemic has underscored the critical importance of hygiene practices in preventing the spread of infectious diseases, including COVID-19 (Banik et al., 2024). Public restrooms, due to their high traffic and potential for contamination, necessitate meticulous hygiene protocols to protect public health (Michael et al., 2022). Existing research highlights the potential risks associated with manual flush systems in these settings, as they require physical contact, potentially facilitating the spread of pathogens (Carole et al., 2020).

Automatic flush systems offer a promising solution to address the hygiene concerns associated with manual flushing. Existing research explores the effectiveness of various types of automatic flush systems in reducing pathogen transmission risks (e.g., sensor-based, foot-operated) (Sarah et al., 2021). While these systems offer benefits, limitations such as high cost, complex installation, or potential hygiene concerns remain (Paz et al., 2024).

The SMUF project leverages ultrasonic motion-detection technology, a robust and accurate method for detecting user presence (Meng et al., 2022). This technology, as demonstrated in various applications like automatic doors and hand dryers, offers a non-contact and efficient solution for triggering automatic flushes (Lopes et al., 2024). While research explores the benefits of automatic flush systems and ultrasonic technology in various contexts, a gap exists regarding their specific application in public restroom urinals designed for optimal hygiene and cost-effectiveness. Further research is needed to address the following questions; How is the effectiveness of ultrasonic motion-detection technology compared to other sensor types in automatic urinal flush systems? Can a battery-powered design using ultrasonic technology offer a cost-effective and versatile solution for public restroom implementation compared to existing automatic flush systems? Do ultrasonic motion-detection systems in public restroom urinals pose any potential hygiene concerns that require further investigation?

By addressing these knowledge gaps, the SMUF project aims to contribute to the development of innovative and effective solutions for promoting public health and hygiene in restrooms.

Research Methodology

Recognizing the critical role of iterative design and testing in the development process, the SMUF project employed a prototyping approach (Nieveen, 1999; Kang et al., 2023). This methodology commenced with conceptualization, which involved thoroughly understanding the problem statement and utilizing this knowledge to create an initial design incorporating ultrasonic motion-detection technology. The development of the SMUF project adhered to a defined methodology encompassing requirement specification, prototyping, and testing phases.

NATIONAL ENGITECH DIGEST

VOL. 1 ISSUE 1

e-ISSN: 3030-5969

The foundation of the project involves establishing a comprehensive set of functional and non-functional requirements. These requirements guide the development process, ensuring the device meets its intended functionality and providing a positive user experience. Functional requirements outlined the core operation of the device: functioning as an automatic urinal flush system triggered by user presence detected through an ultrasonic sensor. The detailed breakdown of functionalities includes user detection, signal processing, flush activation, and the flushing mechanism itself. Non-functional requirements focused on aspects beyond the core functionality. User feedback was addressed by incorporating LED indicators within the device's waterproof casing to provide visual cues regarding its current state. Portability was achieved through battery operation, eliminating the need for permanent wiring and facilitating installation in various locations. Finally, the system's design aimed for versatility, allowing potential reprogramming for use as an automatic flush for standard toilets.

Following the established requirements, the project utilized an iterative prototyping and testing approach to refine the SMUF device's design and functionality. This involves creating multiple prototypes and continuously incorporating feedback from rigorous testing. Each prototype underwent a series of tests to assess its performance and user experience. Functionality testing ensured the device reliably triggered the flush upon user presence and absence. User experience testing gathered feedback from potential users to evaluate the ease of use, intuitiveness, and overall satisfaction with the device. Performance testing measured water usage, battery life, and response time of the system. Figure 1 shows the schematic diagram of SMUF.

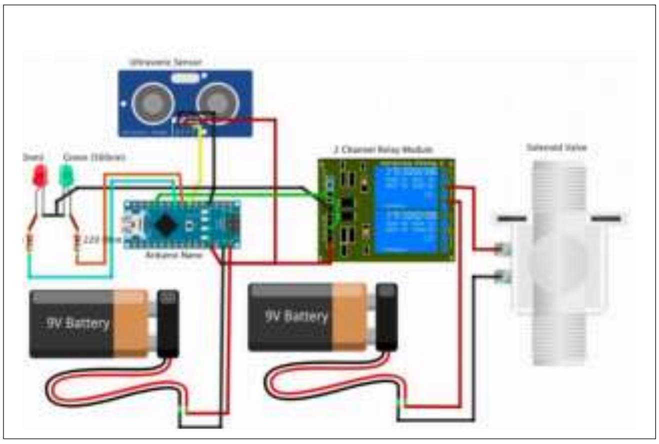

Figure 1. The SMUF's Schematic Diagram

The SMUF project prioritizes a user-friendly and intuitive physical interface. Employing a minimalist approach, the design utilizes two LEDs – red and green, respectively – to effectively communicate essential information throughout the system's operation. During standby mode, the red LED illuminates, clearly indicating that the device is ready for use. This immediate visual cue allows users to quickly understand the device's status without requiring further interaction.

Upon user detection, the green LED initiates a flashing sequence, signifying a 3-second period to prevent false activation. This dynamic display enhances user's awareness during the detection phase. Subsequently, the green LED switches to a solid glow, indicating that the flush is ready to be activated. This clear visual confirmation ensures users are informed and prepared to engage the touchless flushing mechanism.

Following completion of the user's activity, the red LED starts flashing, signaling the initiation of the flushing process. This visual feedback keeps users aware of the ongoing operation. Once flushing concludes, the device seamlessly transitions back to standby mode, indicated by the red LED illumination. The strategic placement and use of these LEDs within the physical design significantly enhance user interaction. This simple yet effective interface provides clear and comprehensible visual cues, guiding users through the Smart Motion Flush's operation effortlessly.

The SMUF prioritizes a user-friendly interface with only two LEDs: red and green. The red LED signifies standby mode (Figure 2), indicating the device is ready for use. Upon user detection, the green LED flashes for 3 seconds (Figure 3) to prevent false activation, then turns solid green to show the flush is ready. Once the user has finished and moved away, the red LED flashes during the flushing process before returning to standby mode. This simple and intuitive design provides clear visual cues throughout the device's operation, eliminating the need for complex instructions.

Figure 3: SMUF's detection period

NATIONAL ENGITECH DIGEST

VOL. 1 ISSUE 1

e-ISSN: 3030-5969

Figure 2: SMUF's Standby mode

Analysis and Discussion

The final comprehensive testing phase of the SMUF project encompassed various testing levels to ensure comprehensive validation. Unit testing meticulously evaluated the functionality of individual components, including the ultrasonic sensor, microcontroller, and solenoid valve. This rigorous assessment verified the performance of each element in isolation, laying the foundation for successful system integration.

System testing then focused on the complete system, assessing its ability to meet the established requirements. This involved testing the:

1. Functionality: Seamless operation of the automatic urinal flush, including accurate detection by the ultrasonic sensor and initiation of the flush sequence only after user presence for a specified duration.
2. Performance: Water usage, battery life, and response time of the system.
3. User experience: Effectiveness of the LED indicators in providing clear visual cues for various states of the system.

Importantly, the system testing confirmed that the flushing process occurred as expected upon user departure.

User acceptance testing (UAT) further validated the project's success by simulating real-world user interaction. This final stage involved potential users interacting with the device to assess its usability, intuitiveness, and overall satisfaction. The positive feedback received during UAT confirmed the user-friendliness and effectiveness of the SMUF design. The successful completion of these various testing stages, from unit testing to UAT, provided comprehensive validation of the SMUF project's functionality, performance, and user-centric design.

Table 1: The SMUF Unit Testing Results

Test Case Name	Test Procedure	Pre-condition	Expected Result	Tester	Result (Pass/Fail)
Ultrasonic sensor	Checking if the ultrasonic sensor detects the user.	Coding implemented to the Arduino and connected the sensor.	Detects the user when at least 50 cm from the sensor.	Tester 1	Pass
LEDs	Checking if the LEDs Function.	Connected to Arduino with power supply.	Both green and red LEDs light up.	Tester 2	Pass
Solenoid	Checking if the solenoid opens and closes the valve to allow water to flow through.	Coding implemented to the Arduino and connected the solenoid.	The solenoid opens for 3 seconds to allow water to flow through then close.	Tester 3	Pass

Table 2: The SMUF Integration Testing Results

Test Case Name	Test Procedure	Pre-condition	Expected Result	Tester	Result (Pass/Fail)
LED response integration with the rest of the system	Simulate a flush activation by triggering the ultrasonic sensor to check if the LEDs light up according to the current process taking place.	Coding implemented to Arduino for the LEDs to flash and glow according to the process taking place.	The red LED glows red when the device is in standby mode. Flash green when the sensor detects the user. Glows green when the system is ready to flush. Flash red when flushing occurs.	Tester 1 and 2	Pass
Flushing	Simulate a flush activation by triggering the ultrasonic sensor to check if the solenoid function is Integrated.	This coding implemented for the solenoid to activate when user is detected by the ultrasonic sensor.	The solenoid to open the water inlet valve for 3 seconds after the ultrasonic sensor has detected the user for 3 seconds or more than moves Away.	Tester 2 and 2	Pass

Conclusion and Recommendation

The SMUF project has successfully addressed limitations associated with traditional manual urinal flush systems, offering a cost-effective, hygienic, and environmentally friendly alternative. Its advantages are evident in several aspects. Firstly, the sensor-driven flush system minimizes water wastage by regulating the amount of water used per flush, contributing to environmental conservation and sustainability. This aligns with the growing global focus on water conservation efforts. Secondly, the automatic urinal flush significantly improves hygiene and sanitary conditions, particularly beneficial in high-traffic commercial spaces. It eliminates the need for human contact, reducing the risk of germs and contamination, especially relevant in the post-COVID era. Thirdly, the sensor-driven urinal provides a solution to the reluctance associated with touching public bathroom fixtures, addressing the heightened concerns related to surface contact and contagion, crucial in a post-pandemic context. Finally, the project introduces a durable and long-lasting solution with sensor flush valves, minimizing wear and tear compared to manual flush valves. This not only decreases maintenance costs but also extends the lifespan of the flushing system.

Despite the project's success, certain limitations deserve acknowledgment. The first limitation is the reliance on 9V batteries, which limits the device's continuous operation. To address this, periodic battery replacement is required. Future iterations could explore alternative power sources or improved battery efficiency to enhance user convenience and reduce reliance on disposable batteries. Secondly, repurposing the current urinal sensor for toilet flushing would necessitate reprogramming due to different flushing duration requirements. Future developments could focus on universalizing the sensor's adaptability for various restroom fixtures, making the system more versatile and applicable in diverse settings.

To further enhance the SMUF project and expand its applicability, future endeavors could explore several areas. Firstly, investigating energy-efficient technologies or alternative power sources could extend the device's operational lifespan without compromising portability. This would contribute to a more sustainable solution in the long run. Secondly, developing a versatile sensor system that can be easily reprogrammed to adapt to different flushing durations would cater to both urinals and standard toilets. This would increase the system's flexibility and broaden its potential market for widespread adoption.

In conclusion, the SMUF project aims to introduce an affordable and practical automatic urinal flush system suitable for widespread adoption in public restrooms. The emphasis on hygiene and water conservation aligns with the global imperative for sustainable and safe sanitation practices. This project serves as a steppingstone towards revolutionizing restroom technology and contributing to a safer, more environmentally conscious future.

References

Banik, S. K., Bristy, S. S., Alam, T. A. I., Das, M., & Rizwan, A. A. M. (2024). Socio-economic dimensions of handwashing knowledge in student populations at Ukhiya subdistrict of Coxâ€™ s Bazar, Bangladesh. International Journal of Science and Business, 33(1), 155-163.

Carole, Hallam., Andrea, Denton., Gary, Thirkell. (2020). COVID-19: considerations for the safe management and disposal of human excreta. doi: 10.1016/J.INFPIP.2020.100085.

Kang, B., Crilly, N., Ning, W., & Kristensson, P. O. (2023). Prototyping to elicit user requirements for product development: Using head-mounted augmented reality when designing interactive devices. Design Studies, 84, 101147.

Lopes, S. I., Pinho, P., Marques, P., Abreu, C., Milheiro, J., Braga, B., ... & Carvalho, N. B. (2024). CoViS: A Contactless Health Monitoring System for the Nursing Home Lessons learned from practice. IEEE Access.

Meng, L., Chang, L., & Hou, J. (2022). Degradation of methyl green from wastewater with ultrasound synergized with Bi2O2CO3 catalysis: Kinetics, products, and pathways. Journal of Cleaner Production, 342, 130976.

Michael, J., Plank., Alex, James., Audrey, Lustig., Nicholas, Steyn., Rachelle, N., Binny., Shaun, C., Hendy. (2022). Potential reduction in transmission of COVID-19 by digital contact tracing systems: a modelling study. Mathematical Medicine and Biology-a Journal of The Ima, doi: 10.1093/imammb/dqac002.

Nieveen, N. (1999). Prototyping to reach product quality. Design approaches and tools in education and training, 125-135.

Paz, E. F. M., Raskin, L., Wigginton, K. R., & Kerkez, B. (2024). Toward the autonomous flushing of building plumbing: Characterizing oxidation-reduction potential and temperature sensor dynamics. Water Research, 251, 121098.

Sarah, E., Abney., Kelly, R., Bright., Julie, McKinney., M., Khalid, Ijaz., Charles, P., Gerba. (2021). Toilet Hygiene - Review and Research Needs. Journal of Applied Microbiology, doi: 10.1111/JAM.15121.