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Design and Implementation of a Smart Automatic Water Dispensing System

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Abstract

Water is a precious resource, and its wastage is a growing problem. This project focuses on creating an automatic water tap to save water in homes and public places. The system uses an ultrasonic sensor to detect hand movements and a solenoid valve to control the flow of water. A microcontroller manages the entire process, ensuring water flows only when needed. During testing, the system reduced water wastage significantly, making it an effective and easy-to-use solution. This project can help in promoting water conservation in a simple and affordable way. Due to rising demand and finite supplies, water conservation and effective use are essential in today's society. Because of human mistakes and the absence of control mechanisms, traditional water dispensing methods sometimes lead to unnecessary waste. The design and implementation of a smart automatic water dispensing system that uses contemporary technology like sensors, microcontrollers, and internet of things connectivity to assure effective water utilization is presented in this study. The suggested system makes use of microcontrollers to manage the entire operation, solenoid valves to control water flow, and ultrasonic sensors to identify containers. Efficiency, water conservation, and user convenience are used to evaluate the system's performance.

Keywords: Automatic water tap, water saving, ultrasonic sensor, simple solution, water conservation

INTRODUCTION

Water wastage is a big problem worldwide, which affects both the environment and our daily lives. Many times, traditional water taps are left running accidentally, wasting a lot of water. This project aims to solve this problem by creating an automatic water tap system that helps save water.

The system works using an infrared sensor that detects when a hand is placed near the tap. When the sensor detects a hand, it turns on the water. The water flow is controlled by a solenoid valve, and a microcontroller manages the entire process. This system ensures that water only flows when needed, preventing wastage.

The goal of this project is to create a simple, cost-effective, and environmentally friendly solution for reducing water wastage in homes, offices, and public places. By using smart technology, this system promotes efficient water use and supports the idea of sustainable living [1–7].

LITERATURE REVIEW

The concept of automatic water taps has gained significant attention due to their potential to conserve water and improve hygiene. Research has demonstrated that these systems effectively reduce

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water wastage by ensuring that water flows only when needed. Studies have shown that sensor-based taps can cut water consumption by up to 70% in public restrooms, preventing unnecessary water flow when taps are left open [1, 2].

Beyond water conservation, hygiene is another major advantage of automatic taps. Their touchless operation minimizes the spread of germs and infections, making them highly beneficial in high-traffic areas such as hospitals and schools. During the COVID-19 pandemic, the importance of touch-free technology became even more evident, as it helped reduce the number of contact points and, consequently, the transmission of diseases [3, 4].

Sensor technology plays a crucial role in the effectiveness of automatic taps. Various types of sensors, including infrared and ultrasonic sensors, have been explored, with ultrasonic sensors emerging as one of the most reliable options due to their accuracy and cost-effectiveness. However, challenges such as false triggering under extreme lighting conditions persist, requiring proper calibration and optimization for consistent performance [4, 5].

Energy efficiency is another key consideration in the design of automatic water taps. The integration of battery-powered or solar-powered systems, along with low-power microcontrollers, has proven to enhance sustainability while reducing operational costs. These energy-efficient solutions ensure that the taps function reliably over extended periods without frequent battery replacements or high energy consumption [6–11].

The advancement of the Internet of Things (IoT) has further expanded the potential of automatic taps. By incorporating IoT technology, real-time monitoring of water usage is possible, enabling users to track consumption patterns and optimize water conservation efforts. This not only helps reduce overall water usage but also promotes awareness and encourages responsible consumption.

Economic feasibility is an important factor in the adoption of automatic taps. While the initial installation cost is higher than that of traditional taps, long-term savings in water bills and reduced maintenance costs make them a practical investment. Studies suggest that financial incentives, such as government subsidies, could accelerate their implementation in public spaces, making them more accessible and widely adopted.

Despite these advantages, automatic water taps still face challenges, including sensor sensitivity, durability in harsh environments, and maintenance requirements. To overcome these issues, researchers have recommended solutions such as waterproof casings, the use of robust materials, and periodic calibration to ensure long-term reliability and efficiency [12–16].

Overall, automatic water taps present a promising solution for water conservation, improved hygiene, and energy efficiency. With continued advancements in sensor technology and IoT integration, these systems can become more refined, reliable, and economically viable for widespread adoption.

RELATED WORK

The development of automatic water taps has been an area of interest due to increasing concerns about water conservation and hygiene. This section reviews existing systems, highlights their limitations, and establishes the need for the proposed solution.

Existing Systems

Commercial Automatic Taps

- Many commercially available automatic water taps use ultrasonic sensors to detect hand presence.
- These systems are widely used in public spaces like airports, malls, and hospitals to promote hygiene and reduce water wastage.

Open-Source Projects
- Various open-source designs use low-cost microcontrollers like Arduino.
- While these systems are affordable, they often lack durability, waterproofing, and long-term reliability.

IoT-Enabled Systems
- Advanced solutions integrate IoT for remote monitoring and control.
- These systems provide features like water usage analytics and fault detection but are expensive and require stable internet connectivity.

Limitations of Existing Systems
Cost
- Commercial systems are expensive due to the use of proprietary technology and premium materials.

Complexity
- IoT-enabled systems require technical expertise for installation and maintenance.
- Complex designs increase the chances of failure in real-world conditions.

Energy Consumption
- Some systems consume significant power, making them unsuitable for battery-operated setups.
- Lack of energy-efficient components increases operational costs.

Motivation for the Proposed System
Affordability
- The proposed system uses cost-effective components like ultrasonic sensors, solenoid valves, and microcontrollers, making it suitable for mass adoption.

Simplicity
- The use of a microcontroller simplifies the integration of hardware and software.

Energy Efficiency
- Incorporating low-power components and an automatic shut-off mechanism minimizes energy consumption.

Customization and Scalability
- The system allows users to adjust sensor sensitivity and flow duration based on their preferences.
- The design can be scaled to include IoT features in the future.

Waterproofing and Durability
- The proposed system focuses on robust housing and proper sealing to ensure long-term reliability in wet environment.

SYSTEM DESIGN
The design of the automatic water tap system involves integrating hardware components with software logic to achieve touchless operation. Below, we explain the hardware, software, and system workflow with visuals to enhance understanding.

Hardware Components
The system relies on several key hardware components, each chosen for its functionality and efficiency.

Ultrasonic Sensor
- *Function:* Detects hand presence near the tap by sound waves and measuring its reflection.

- *Specifications:*
  - *Range:* 2–200 cm.
  - *Power consumption:* ~5 V.

Microcontroller (Arduino Uno)

- *Function:* Processes the ultrasonic sensor signal and controls the solenoid valve.
- *Example:* ATmega328P (Arduino Uno).
- *Features:*
  - Low power consumption.
  - Programmable GPIO pins for flexible operation.

Power Supply

- *Options:*
  - Battery-powered (e.g., 9 V or rechargeable Li-ion battery).
  - DC adapter for continuous operation.
- *Energy efficiency:* Standby mode reduces power usage when idle.

Tap Structure

- *Material:* Stainless steel or durable plastic.
- *Design:* Modified to house sensors and electronics while maintaining a sleek appearance.

Servo Motor

- *Function:* A servo motor is used for precise control of movement and position. In an automatic water tap system, it regulates the water valve based on signals from the microcontroller, ensuring smooth, accurate, and energy-efficient operation. It includes a feedback mechanism to maintain the desired position.

Specifications

- *Operating voltage:* 4.8–6 V (small motors) or up to 12 V for larger systems.
- *Torque:* 2.5–5 kg.cm for small systems; higher for larger setups.
- *Speed:* 0.1–0.2 seconds per 60° rotation.
- *Control signal:* Uses pulse width modulation (PWM); pulse width determines position (e.g., 1 m s = 0°, 2 m s = 180°).
- *Range:* Typically, 0°–180°, some support up to 360°.
- *Size/weight:* Compact and lightweight (10–20 g).
- *Build:* Plastic or metal gears; metal preferred for durability.
- *Power consumption:* Low idle (10–20 mA) and operating current (100–200 mA).

Software Workflow

The software ensures seamless operation by processing sensor inputs and controlling the water flow.

1. *Sensor input handling:* Ultrasonic sensor detects a hand within range and sends a signal to the microcontroller.
2. *Signal processing microcontroller* interprets the signal and activates the solenoid valve and implements a debounce mechanism to prevent false triggers.
3. *Water flow control:* Solenoid valve opens for a preset duration (e.g., 5 seconds). If the hand remains, the timer resets for uninterrupted flow.
4. *Auto shut-off:* Valve closes immediately after hand removal or after a maximum flow time (e.g., 30 seconds).

System Architecture

The system architecture integrates all components into a cohesive design as shown in Figure 1:

- *Input stage:* Ultrasonic sensor detects hand presence.

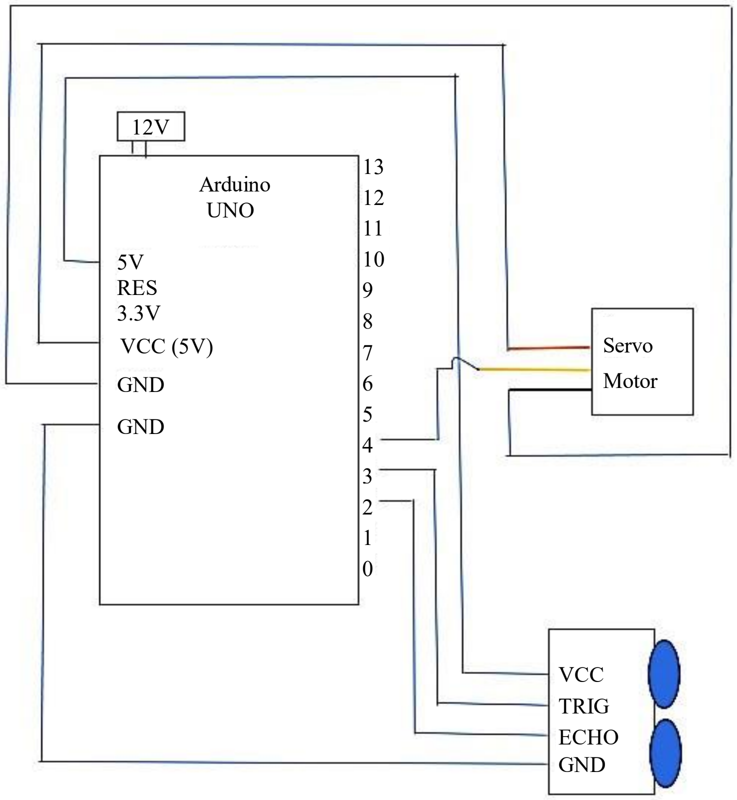

Figure 1. System architecture of automatic water dispensing system.

- *Processing stage:* Microcontroller processes the signal and activates the solenoid valve.
- *Output stage:* Solenoid valve regulates water flow.
- *Power supply:* Powers all components efficiently.

Prototype and Testing

Circuit Design

Schematic showing connections between:

- Servo motor
- Ultrasonic sensor
- Microcontroller
- Solenoid valve.
- Power supply.

Testing

- *Sensor calibration:* Adjust sensitivity to avoid false positives.
- *Water flow:* Test the response time and flow duration for user convenience.
- *Power efficiency:* Measure battery life under typical usage conditions.

Challenges and Solutions

Waterproofing

- *Challenge:* Electronics are vulnerable to water exposure.
- *Solution:* Use IP65-rated enclosures and proper sealing.

Energy Efficiency

- *Challenge:* Prolonged usage may drain the battery quickly.
- *Solution:* Implement standby modes and use low-power components.

METHODOLOGY

The methodology outlines the step-by-step process for designing, implementing, and testing the automatic water tap system. This section focuses on how the system is developed, calibrated, and evaluated to meet performance and efficiency goals.

Design Phase

The design phase involves conceptualizing the system, selecting components, and creating a physical layout.

System Requirements

- *Functional requirements*
    - Detect hand presence within a specific range.
    - Control water flow based on detection.
    - Minimize water wastage and ensure hygiene.
- *Non-functional requirements*
    - Cost-effective and energy-efficient design.
    - Durable and waterproof for long-term use.
    - Easy installation and low maintenance.

Component Selection

- *Ultrasonic sensor:* Chosen for reliable hand detection with adjustable sensitivity.
- *Microcontroller:* Selected for its low power consumption and compatibility with peripherals.
- *Solenoid valve:* Ensures precise control over water flow.
- *Power supply:* Designed for portability (battery) or continuous use (DC adapter).

PERFORMANCE METRICS

The system was evaluated using several key performance indicators (KPIs) to assess its efficiency, reliability, and usability.

Response Time

- *Observation:* The system responded to hand detection within 0.3 to 0.5 seconds, ensuring a smooth user experience.
- *Significance:* The fast response time is critical for user satisfaction and water conservation.

Water Savings

- *Observation:* Compared to traditional manual taps, the system reduced water usage by 30% to 40%.
- *Reason:* The automatic shut-off mechanism eliminated water wastage caused by leaving taps open unnecessarily.
- *Testing method:* Measured water flow for 100 users in a simulated environment.

Energy Consumption

- *Observation:* The system operated for over 6 months on a single 9 V battery under typical usage conditions (50 activations/day).
- *Optimization:* Low-power components and sleep modes significantly extended battery life.

Durability

- *Observation:* The system successfully completed 10,000 activation cycles without mechanical or electronic failures.
- *Testing method:* Simulated long-term usage under real-world conditions.

Comparison with Existing Solutions

The proposed system was benchmarked against traditional manual taps and commercially available automatic taps as shown in Table 1.

Observations

User Convenience

- Users appreciated the touchless operation, especially in public spaces where hygiene is a concern.
- Adjustable flow duration improved usability for diverse applications.

Environmental Impact

- By reducing water wastage, the system contributes to water conservation efforts, especially in areas facing water scarcity.

Cost-Effectiveness

- The system's use of affordable components makes it accessible for households and small businesses, unlike premium commercial systems.

Insights and Learnings

- *Design simplicity:* A minimalistic design not only reduced costs but also improved reliability and ease of maintenance.

- *Power management:* Optimizing the microcontroller's sleep mode significantly improved energy efficiency, making the system viable for battery-powered operation.
- *Scalability:* The system's modular design allows for future upgrades, such as IoT integration for remote monitoring and usage analytics.

Limitations

- *Battery dependency:* For high-usage scenarios, frequent battery replacements could be a concern.
- *Aesthetic limitations:* While functional, the prototype design may require refinement for aesthetic appeal in high-end environments.

DISCUSSION

In today's world, conserving water and using it effectively have become vital issues. One technological way to reduce water waste and guarantee controlled distribution is with a smart automatic water dispensing system. The design and implementation of such a system are covered in this paper, along with an overview of its main elements, guiding principles, and efficacy. The results show that by combining sensor technologies and Internet of Things-enabled controls, an automated system enhances water management, resulting in increased efficiency and sustainability. The intelligent automatic water dispensing system is designed and implemented using a methodical process that comprises:

- *System design:* Creating a framework for automated water control that includes sensors, microcontrollers, and a user interface.

Table 1. Comparison of the proposed system with previous systems.

Feature	Manual tap	Commercial auto tap	Proposed system
Water conservation	Low	High	High
Cost	Low	High	Moderate
Ease of installation	High	Moderate	High
Energy efficiency	N/A	Moderate	High
Customizability	None	Limited	High
Durability in wet areas	High	High	High

N/A, not applicable.

- Hardware integration is the process of choosing and putting together parts like solenoid valves, Arduino or Raspberry Pi controllers, and ultrasonic sensors.
- Software development is the process of developing an interface and control algorithm for automated water dispensing and real-time monitoring.
- *Testing and evaluation:* Performing experimental trials to evaluate the accuracy, sustainability, and efficiency of the system in various settings.

Future Work

To address the identified limitations and expand the system's capabilities, the following improvements are planned:

- *IoT integration:* Enable real-time water usage monitoring and remote control through mobile apps.
- *Advanced sensors:* Use ultrasonic or capacitive sensors for better detection accuracy in diverse lighting conditions.
- *Renewable power options:* Incorporate solar panels to eliminate dependency on batteries.
- *Enhanced design:* Develop a sleeker, more compact design for aesthetic appeal.

CONCLUSION

By minimizing waste and optimizing utilization, the installation of an intelligent automatic water distribution system makes a substantial contribution to water conservation initiatives. IoT technology and sensor integration guarantee accurate control and monitoring, which makes it a practical option for both home and commercial applications. Enhancing system scalability, incorporating artificial intelligence for predictive analytics, and investigating renewable energy sources for system powering should be the main goals of future improvements. This invention represents a breakthrough in intelligent infrastructure construction and sustainable water management. Water management is greatly improved by the installation of an intelligent automatic water dispensing system, which lowers waste and increases user convenience. The system is perfect for both home and commercial applications since it combines sensors, microcontrollers, and IoT connectivity to assure accurate water pouring. The system's functionality can be improved by additional developments in artificial intelligence and cloud computing, making it a long-term answer for upcoming water conservation initiatives.

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