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RESEARCH ARTICLE

EMBEDDED SYSTEM BASED SOLUTION FOR WATER LEVEL MONITORING AND CONSERVATION

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Abstract

Water is an essential natural resource for sustaining life on Earth, and its effective management has become a global imperative due to population growth and fast urbanization. Conventional techniques for monitoring water levels in overhead tanks, reservoirs, or irrigation systems frequently exhibit inefficiency, require considerable time, and are susceptible to human mistake. This research proposes an embedded system method for monitoring and conserving water levels to solve these difficulties. The device employs an ultrasonic sensor (HC-SR04) to precisely measure the water level within a tank without direct contact with the liquid, hence ensuring the sensor's safety and durability. The acquired data is processed by an Arduino Uno microcontroller, which serves as the system's central processing unit and autonomously regulates a relay module linked to a water pump. When the water level falls below a specified threshold, the system engages the pump to replenish the tank, and when the tank attains its maximum capacity, the pump is automatically deactivated. A 16x2 I2C LCD display is utilized to convey real-time water level data and pump status, hence improving user engagement and system clarity. A buzzer alert is incorporated to indicate severe water conditions or system failures. This automation saves water wasted from overflow and reduces energy consumption by optimizing pump operation. The proposed system is economical, compact, and appropriate for residential, agricultural, and industrial uses. Implementing this embeddedmonitoring system enables users to assuresustainable water management, enhance operational efficiency, and contribute to comprehensive water conservation initiatives. Moreov er, the initiative underscores the potential of embedded systems to create intelligent, environmentally sustainable solutions for pressing ecological challenges, advancing the overarching concept of smart and sustainable living.

Introduction:-

Water is a fundamental natural resource necessary for all living beings, industrial processes, and agricultural activities. Nonetheless, the swift population development, industrialization, and urban expansion have substantially heightened the demand for water, resulting in considerable depletion of water resources. In numerous regions globally, ineffective water management techniques, unregulated usage, and waste from overflow or leakage have led to a significant shortage of clean water. Consequently, the establishment of an intelligent and automated system for monitoring and regulating water levels has emerged as an essential measure for sustainablewater conservation. Conventional techniques for monitoring and regulating water levels, such as manually activating and deactivating the water pump, are antiquated, labor-intensive, and susceptible to errors. In several residences, the pumppersistsin operation even after the water tankreachescapacity, resulting in overflow and water wastage. Conversely, a water level monitoring system based on embedded systems offers a dependable, precise, and efficient solution by employing sensors, microcontrollers, and automation methods to continuously assess the water level and autonomously regulate motor activity.

The suggested system employs an Arduino Uno microcontroller as the primary processing unit. The device acquires data from an ultrasonic sensor (HC-SR04), which measures the distance between the sensor and the water surface. The Arduino calculates the water percentage in the tank based on this data. When the water level descends within a specified minimum threshold, the system activates the water pump via a relay module. Upon reaching maximum capacity, the mechanism automatically deactivates the pump, thus averting overflow. The LCD display offers real-time information on water level % and pump functionality, while a buzzer alerts the user in the event of irregular conditions or sensor malfunctions. This guarantees user convenience and system reliability. The primary benefit of this method is its simplicity, cost-effectiveness, and precision. It is simple to install and can be utilized in residential, educational, commercial, and agricultural settings where water management is paramount.

This system integrates embedded technology to reduce human intervention and energy usage while enhancing water conservation efficiency. Furthermore, as the system functions autonomously, it guarantees the optimal utilization of available water resources and mitigates both underflow and overflow scenarios. The significance of water conservation is paramount in light of global climate change and rising demand. Initiatives such as this advocate for intelligent water management, congruent with the objectives of sustainable development. Embedded systems provide a scalable framework for the development of intelligent automation systems, which can be augmented with Internet of Things (IoT) connectivity for remote monitoring and data logging in subsequent iterations.

Literature Review:-

In recent years, numerous research investigations and practical applications have been conducted to create automatic water level monitoring systems utilizing embedded technologies. The aim of these systems is to efficiently monitor, control, and preserve water by removing manual involvement and promoting sustainable water management. Diverse methodologies have been suggested for quantifying water levels and automating motor regulation. Certain systems utilize float sensors or conductive probes that offer a direct measurement of water level via electrical contact. Nonetheless, these conventional sensors are prone to corrosion, require maintenance, and exhibit diminished accuracy over time. Conversely, ultrasonic sensors like the HC-SR04 have become favored for their non-contact functionality, enhanced accuracy, and dependability across various environmental conditions. Numerous researchers have investigated various microcontroller platforms, including Arduino, PIC, and Raspberry Pi, for the implementation of water level monitoring. Arduino Uno-based systems are extensively utilized due to their affordability, programming simplicity, and compatibility with numerous sensors and modules. Research indicates that employing an ultrasonic sensor connected to Arduino enables precise real-time detection of water levels without direct contact with the liquid surface.

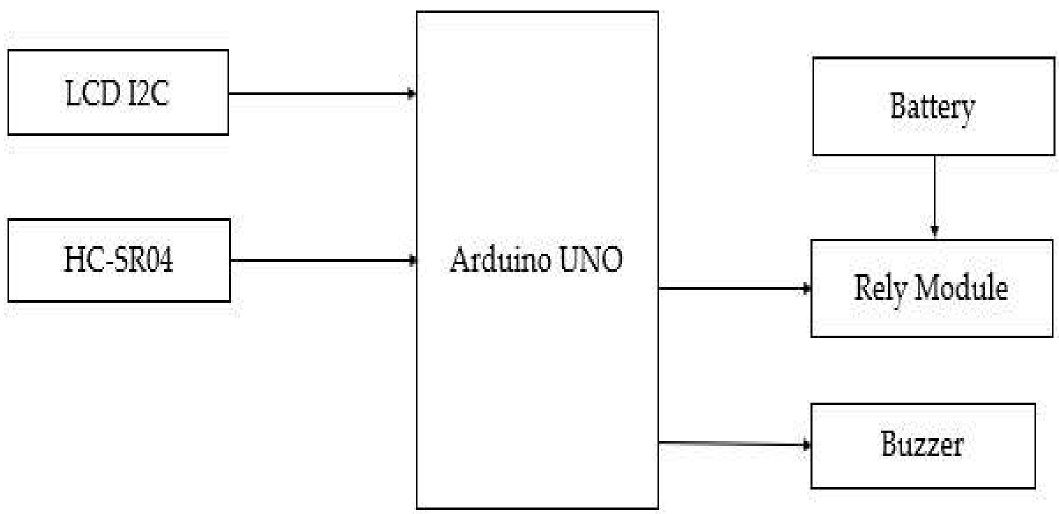
The gathered data can be exhibited on an LCD screen or supplied wirelessly to a mobile application or IoT platform for remote monitoring. In a prior study, researchers developed a GSM-based water level control system that transmitted notifications to the user's phone when the tank reached full or empty status. A further study employed an IoT-based system utilizing NodeMCU and the Blynk application to remotely manage the motor and evaluate water consumption data. While these technologies offer enhanced monitoring capabilities, they elevate system costs and complexity, rendering them less appropriate for small-scale applications. Recent research highlights energy-efficient embedded systems that autonomously monitor water levels and control pump operations without human intervention. These systems incorporate low-power microcontrollers, real-time sensors, andsophisticated decisionmaking algorithms toenhance water efficiency. Furthermore, enhancements in sensor calibration and relay control modules have markedly augmented the stability and efficacy of autonomous pump systems.

The literature study indicates that the integration of ultrasonic sensor technology with Arduino-based control offers a straightforward and efficient solution for autonomous water level monitoring and conservation. This technology reduces water waste, optimizes motor efficiency, and necessitates minimum upkeep compared to traditional techniques. This evaluation emphasizes the necessity for a cost-efficient, intuitive, and dependable embedded system capable of continually monitoring water levels and autonomously managing pump control. This study presents a system that tackles these deficiencies by incorporating real-time monitoring, automated pump operation, visual display via LCD, and alert notifications through a buzzer, all realized through a compact and cost-effective embedded design.

System Design and Methodology:-

The suggested system is engineered to autonomously monitor and regulate the water level in a tank utilizing an Arduino UNO microcontroller as the primary processing unit. The system has sensors and output modules that provide accurate measurement and automated control, hence ensuring effective water utilization and conservation.

System Architecture The system's block diagram comprises the following primary components:



1.ArduinoUNO
2. Ultrasonic Sensor (HC-SR04)
3. LCD Display (I2C)
4. Relay Module
5. Battery
6. Buzzer

Operating Principle:-

The HC-SR04 ultrasonic sensor is positioned atop the water tank. It quantifies the distance from the sensor to the water surface utilizing ultrasonic sound waves. The Arduino UNO computes the water level percentage within the tank based on this distance. The I2C LCD display indicates the current water level and the pump status (ON/OFF/AUTO). When the water level drops below a predetermined threshold (e.g., 20%), the Arduino engages the relay module, which subsequently operates the water pump. Upon reaching the upper limit of water level (e.g., 90%), the relay deactivates the pump to avert overflow. The battery supplies electricity to the entire circuit, ensuring consistent voltage for all components. A buzzer is integrated into the system to provide alerts when the tank is approaching emptiness or fullness, functioning as an extra safety and alerting mechanism.

Methodology:-

Initialization:

(i) Upon powering ON the system, the Arduino initializes the LCD and sensor modules.
(ii) (ii)The LCD presents a welcome greeting and configures the machine to AUTO mode.

Water Level Detection:

(i) The HC-SR04 ultrasonic sensor emits an ultrasonic pulse.
(ii) (ii)The echo time is returned and transformed into a distance measurement.
(iii) (iii)The Arduino utilizes this distance to ascertain the percentage of the water level.

Data Presentation:

(i) The computed water level percentage is exhibited on the LCD I2C module in real-time.
(ii) (ii)The pump status is indicated as "PUMP ON," "PUMP OFF," or "AUTO."

Pump Control via Relay Module:

(i) When the water level falls below the minimal threshold, the Arduino engages the relay to activate the pump.
(ii) When the tank attains the maximum water level, the relay automatically deactivates the pump.
(iii) This automatic switching minimizes personal intervention and mitigates water wasting and motor damage.

Alert System:

(i) The buzzer emits an alert when the tank is either depleted or filled to capacity.
(ii) (ii)This guarantees user awareness without the need for constant observation of the LCD display.

electricity Supply:

(i) A battery provides electricity to the system, guaranteeing continuous operation despite fluctuations in the main power supply.

Benefits of the Design:-

Completely automated system requiring minimal human involvement. Prevents overflow and dry operation of the motor. Simple, economical, and energy-efficient design. Facilitates water saving by regulating superfluous waste. Delivers real-time level notifications via LCD display and auditory alert.

Results and Discussion:-

The Automatic Water Level Monitoring and Control System was effectively created, implemented, and tested utilizing the components outlined in the system design. The experimental configuration was established using a small-scale prototype to replicate the functionality of an actual residential water tank control system.

Experimental Configuration:

The entire hardware configuration of the system is illustrated in Fig. 1. The circuit comprises an Arduino UNO microcontroller, HC-SR04 ultrasonic sensor, LCD I2C display, relay module, buzzer, and battery. All components were meticulously arranged into a transparent plastic container for security and facile observation. The ultrasonic sensor was positioned at the upper edge of a water container, directed downward toward the water surface. The container served as a representation of a domestic water reservoir.

Figure 1. Prototype configuration of the water level monitoring and control system.

Upon powering ON the system, the Arduino commenced acquiring distance measurements from the ultrasonic sensor. The water level % was computed based on the measured distance between the sensor and the water surface. The Arduino evaluated the computed level against established threshold limits to autonomously regulate the water pump.

Documented Result:-

The LCD monitor consistently updated the water level % and pump status in real-time. As illustrated in Fig. 2, when the water level reached around 22%, the system automatically activated the water pump, and the display indicated: > Water Level: 22% Pump: Activated In Automatic Mode This verifies that the system appropriately activated the pump via the relay module in response to low water levels.

Figure 2. LCD display indicating water level percentage and pump status.

As water was introduced into the container, the ultrasonic sensor persistently monitored the rising water level, and the LCD displayed the corresponding updated values. Upon reaching the predetermined upper water level threshold (e.g., exceeding 90%), the Arduino transmitted a signal to the relay to deactivate the pump, while the buzzer produced a brief alert tone to signify that the tank was full.

Evaluation of Performance:-

The prototype exhibited exceptional precision in identifying and presenting water levels. The ultrasonic sensor delivered consistent readings with negligible variation. The relay module effectively managed the pump operation instantaneously, guaranteeing seamless transitions between ON and OFF states. The LCD I2C module exhibited crisp and accurate messages even in ambient illumination conditions. The buzzer alarm efficiently signaled elevated or diminished water levels, enhancing safety through overflow and dry-run protection. The system necessitated no operator intervention, confirming the automated nature of the design. During many test runs, the system maintained constant performance with an average response time of less than one second between water level change and LCD update. Power consumption was negligible owing to the low-voltage functionality of all components.

Summary of Findings:-

The aforementioned observations indicate that the Arduino-based water level monitoring system functions efficiently in detecting water levels, automating motor operations, and presenting real-time data on the LCD. The technology is precise, economical, and appropriate for practical applications including residential tanks, industrial reservoirs, and agricultural irrigation systems.

Conclusion:-

The proposed Embedded System Solution for Water Level Monitoring and Conservation has been effectively designed, implemented, and tested. The system employs an Arduino UNO microcontroller, HC-SR04 ultrasonic sensor, relay module, LCD I2C display, buzzer, and battery to autonomously monitor and regulate the water level in a tank. The findings indicate that the system can accurately gauge the water level percentage and provide it in real time on the LCD panel. When the water level descends beneath a specified threshold, the Arduino autonomously engages the pump via the relay module. Upon reaching maximum capacity, the pump is automatically deactivated, and the buzzer emits an alert sound.This design obviates manual monitoring, prevents water overflow, and reduces power wastage. It provides an economical, dependable, and energy-efficient solution appropriate for both residential and industrial water management applications. The created prototype illustrates the application of embedded technology for intelligent water management and conservation, enhancing sustainable resource utilization. Future enhancements may encompass IoT-enabled remote monitoring, mobile alerts, and management and conservation, enhancing sustainable resource utilization. Future enhancements may encompass IoT-enabled remote monitoring, mobile alerts, and solar-powered operation to augment functionality and promote environmental sustainability.

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