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Full Length Article

Smart Underground Drainage Monitoring System For Urban Safety

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Abstract:
The development of smart cities represents a forward-looking vision aimed at creating cleaner, more sustainable, and efficient urban environments that enhance the quality of life for residents. A critical yet often overlooked component of smart city infrastructure is the effective management of underground systems, particularly drainage networks. Proper monitoring of drainage systems plays a vital role in maintaining public health, preventing waterlogging, and ensuring overall urban cleanliness. Traditional manual inspection and monitoring of drainage systems are inefficient, time-consuming, and prone to delays in identifying and addressing issues such as blockages, overflows, or structural damage. These limitations can lead to environmental hazards, public health risks, and increased maintenance cosSts. To overcome these challenges, this project proposes an intelligent, automated drainage monitoring system based on a Wireless Sensor Network (WSN). The system utilizes low-cost sensor nodes strategically deployed within manholes to continuously monitor key parameters such as water level, gas concentration, and structural integrity. The proposed solution is designed to be affordable, low-maintenance, and capable of real-time operation. It employs GSM technology to send instant alerts to the managing authority via email whenever any monitored parameter exceeds predefined threshold values. This proactive approach enables rapid response to potential problems, reducing the risk of accidents and environmental damage.
In addition to improving operational efficiency, the system significantly reduces the dangers faced by manual scavengers who traditionally clean underground drainage systems. By minimizing the need for physical entry into hazardous manholes, it enhances worker safety and promotes more humane and sustainable urban maintenance practices. Ultimately, the system contributes to a cleaner, healthier, and smarter city environment for the benefit of the general public.

Keywords*: Arduino Microcontroller, Arduino IDE, GSM Module, Wireless Sensor Network, Smart City Infrastructure.*

1. Introduction

The concept of smart cities has gained significant momentum worldwide as urban planners and governments strive to create more sustainable, efficient, and livable environments. By integrating advanced technologies such as the Internet of Things (IoT), wireless communication, and intelligent data analytics, smart cities aim to enhance public services, optimize resource utilization, and improve the overall quality of life for residents. Among the many critical components of smart urban infrastructure, effective management of underground systems — particularly drainage networks — remains a vital yet challenging aspect. Drainage systems play an essential role in maintaining urban hygiene, preventing waterlogging, and protecting public health. However, traditional manual monitoring and maintenance practices are often inefficient, time-consuming, and inadequate for addressing issues such as blockages, overflows, or structural damage in a timely manner. These limitations can lead to environmental hazards, increased maintenance costs, and potential health risks for both residents and sanitation workers.

To address these challenges, this project proposes an intelligent, automated drainage monitoring system based on a Wireless Sensor Network (WSN). The system is designed to provide real-time monitoring of critical parameters inside manholes, including water levels, gas concentrations, and structural conditions. By leveraging low-cost, low-power sensor nodes and GSM-based communication, the proposed solution enables instant alerts to be sent to the concerned authorities via email whenever any monitored parameter exceeds predefined threshold values.

This proactive approach significantly improves response times, reduces the risk of accidents, and minimizes the need for manual intervention in hazardous underground environments. The system is

particularly beneficial for manual scavengers, whose safety is often compromised during traditional cleaning operations. By reducing physical entry into dangerous manholes, the solution promotes safer and more humane urban maintenance practices.

The primary objective of this project is to develop a reliable, cost-effective, and scalable IoT-based drainage monitoring system that contributes to the vision of smarter, cleaner, and healthier cities. By combining affordable hardware, wireless communication, and intelligent alerting mechanisms, the system offers a practical and impactful solution for modern urban infrastructure management.

This introduction sets the foundation for the subsequent chapters, which detail the system architecture, hardware and software components, implementation methodology, and expected outcomes of the proposed smart drainage monitoring solution.

2. Project Description

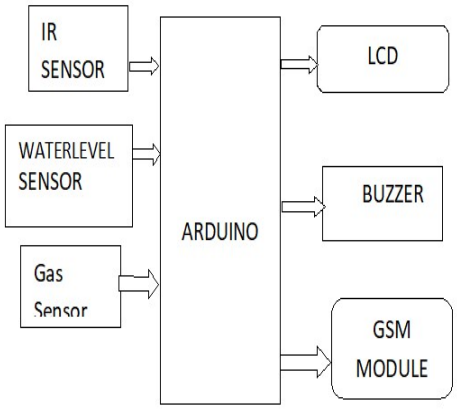
Existing Method

Current drainage systems in most urban areas lack advanced technological integration. As a result, identifying the exact location of blockages is often challenging and time-consuming. Early warning mechanisms are typically absent, leading to delayed detection and repair activities. When drainage pipes become completely blocked, the situation becomes highly inconvenient, causing waterlogging, unhygienic conditions, and significant inconvenience to the public.

Proposed Method

The proposed system introduces a GSM-based drainage and manhole monitoring solution designed for real-time oversight. The system continuously monitors water levels in drains and the status of manhole lids. Predefined maximum threshold levels are set for critical parameters. Sensors deployed in the drainage network continuously track changing conditions. When any monitored parameter reaches or exceeds the set threshold, the sensors immediately detect the anomaly and send a signal to the central controller. The controller then instructs the GSM module to send instant alerts to the municipal corporation or concerned authorities, enabling prompt response and preventive action.

BLOCK DIAGRAM



3. Related Work

Several researchers have made significant contributions to the development of wireless sensor networks and IoT-based monitoring systems. The following section summarizes some of the notable works relevant to this project.

Römer and Mattern (Year) explored the broad design space of wireless sensor networks. Their work highlights how these networks have been applied across diverse domains with varying requirements and characteristics. The authors emphasize the challenges of defining standard hardware and software solutions due to the multidisciplinary nature of the field. They argue that effective collaboration between application experts, hardware designers, and software developers is essential. By analyzing different applications, the paper illustrates how specific systems occupy distinct positions within the overall design space of wireless sensor networks.

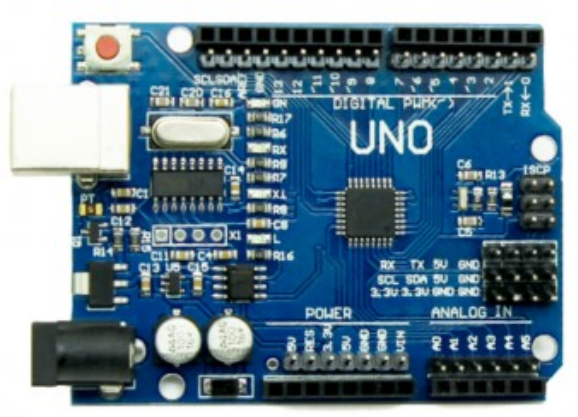
Kelly, Suryadevara, and Mukhopadhyay (Year) presented a practical implementation of an IoT-based system for monitoring domestic environmental conditions. Their architecture integrates low-cost ubiquitous sensing units with a robust network framework for reliable data collection and transmission. The system incorporates pervasive sensing, data aggregation, and context-aware reasoning. Experimental results demonstrated high reliability, with a 97% success rate in data transmission. The prototype successfully generated real-time graphical representations of environmental parameters, validating its effectiveness for smart home monitoring applications.

Shaikh and Sonawane (Year) proposed a Raspberry Pi-based IoT system for smart city applications. The design focuses on monitoring various urban resources to support better management and sustainable development. The system employs multiple sensors to collect real-time data, which is processed by a Raspberry Pi 3 controller. The processed information is transmitted to a central monitoring station via email and displayed on a personal computer. This approach demonstrates how IoT and Raspberry Pi technology can be effectively utilized to create intelligent, responsive urban infrastructure.

The application of Internet of Things (IoT) technologies in healthcare has witnessed rapid growth, with numerous researchers proposing innovative solutions for remote patient monitoring, real-time data acquisition, and intelligent alert systems. This section reviews some of the significant contributions in this field.

Mohd. Hamim et al. developed a prototype IoT-based remote health monitoring system that integrates multiple biomedical sensors, including heart pulse, body temperature, and galvanic skin response sensors. The system utilizes Arduino Uno and Raspberry Pi for data acquisition and processing. Collected data is transmitted to cloud storage, and an Android application provides graphical visualization of vital parameters for easy monitoring by healthcare professionals.

4. Arduino



Overview:

The Arduino Uno is a microcontroller board subject to the ATmega328 (datasheet). It has 14 motorized data/yield pins (of which 6 can be utilized as PWM yields), 6 essential wellsprings of information, a 16 MHz artistic resonator, a USB alliance, a power jack, an ICSP header, and a reset catch. It contains everything expected to help the microcontroller; just interface it to a PC with a USB association or power it with an AC-to-DC connector or battery to begin.

The Uno contrasts from every first board in that it doesn't utilize the FTDI USB-to-back to back driver chip. Or on the other hand possibly, it joins the Atmega16U2 (Atmega8U2 up to change R2) adjusted as a USB-to-successive converter.

The Uno board has a resistor dismantling the 8U2 HWB line to ground, making it less mind boggling to put into DFU mode.

The board has the going with new highlights:

pinout: included SDA and SCL pins that are close to the AREF stick and two other new sticks set close to the RESET stick, the IOREF that engage the shields to adapt to the voltage gave from the board. In future, shields will be extraordinary with both the board that uses the AVR, which works with 5V and with the Arduino Due that works with 3.3V. The resulting one is a not related stick, that is set something aside for future purposes.

- Stronger RESET circuit.
- Atmega 16U2 uproot the 8U2.

"Uno" suggests one in Italian and is named to check the top tier section of Arduino 1.0. The Uno and structure 1.0 will be the reference changes of Arduino, pushing ahead. The Uno is the most recent in a development of USB Arduino sheets, and the reference model for the Arduino compose; for an examination with past structures, see the archive of Arduino sheets.

Gsm
(Global System For Mobile Communication)

GSM (GLOBAL SYSTEM FOR MOBILE COMMUNICATION) is the most popular standard for mobile telephony systems in the world. The GSM Association, its promoting industry trade organization of mobile phone carriers and manufacturers, estimates that 80% of the global mobile market uses the standard. GSM is used by over 1.5 billion people across more than 212 countries and territories. This ubiquity means that subscribers can use their phones throughout the world, enabled by international roaming arrangements between mobile network operators. GSM differs from its predecessor technologies in that both signaling and speech channels are digital, and thus GSM is considered a second generation (2G) mobile phone system. This also facilitates the wide-spread implementation of data communication applications into the system.

The GSM standard has been an advantage to both consumers, who may benefit from the ability to

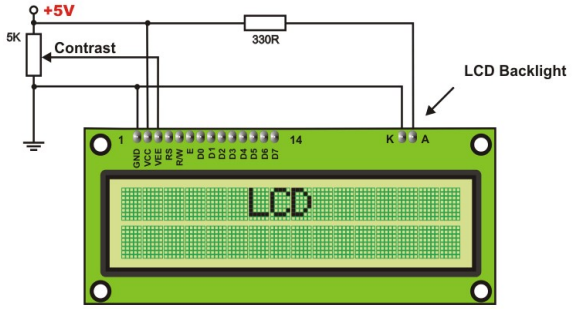
roam and switch carriers without replacing phones, and also to network operators, who can choose equipment from many GSM equipment vendors. GSM also pioneered low-cost implementation of the short message service (SMS), also called text messaging, which has since been supported on other mobile phone standards as well. The standard includes a worldwide emergency telephone number feature (112).

Newer versions of the standard were backward-compatible with the original GSM system. For example, Release '97 of the standard added packet data capabilities by means of General Packet Radio Service (GPRS). Release '99 introduced higher speed data transmission using Enhanced Data Rates for GSM Evolution (EDGE).

Liquid Crystal Display

LCD screen:

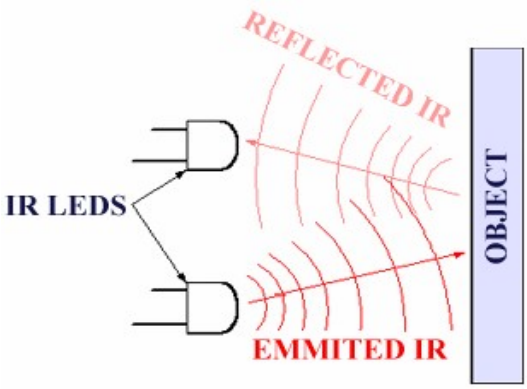
LCD screen consists of two lines with 16 characters each. Each character consists of 5x7 dot matrix. Contrast on display depends on the power supply voltage and whether messages are displayed in one or two lines. For that reason, variable voltage 0-Vdd is applied on pin marked as Vee. Trimmer potentiometer is usually used for that purpose. Some versions of displays have built in backlight (blue or green diodes). When used during operating, a resistor for current limitation should be used (like with any LE diode).



IR SENSOR

IR the same principle in ALL Infra-Red proximity sensors. The basic idea is to send infra red light through IR-LEDs, which is then reflected by any object in front of the sensor.

Then all you have to do is to pick-up the reflected IR light. **For detecting the reflected IR light, we are going to use a very original technique: we are going to use another IR-LED,** to detect the IR light that was emitted from another led of the exact same type. This is an electrical property of Light Emitting Diodes (LEDs) which is the fact that a led produce a voltage difference across its leads when it is subjected to light. As if it was a photo-cell, but with much lower output current. In other words, the voltage generated by the leds can't be - in any way - used to generate electrical power from light, It can barely be detected. that's why as you will notice in the schematic, we are going to use a Op-Amp (operational Amplifier) to accurately detect very small voltage changes.



The sender is composed of an IR LED (D2) in series with a 470 Ohm resistor, yielding a forward current of 7.5mA. **The receiver** part is more complicated, the 2 resistors R5 and R6 form a voltage divider which provides 2.5V at the anode of the IR LED (here, this led will be used as a sensor). When IR light falls on the LED (D1), the voltage drop increases, the cathode's voltage of D1 may go as low as 1.4V or more, depending on the light intensity. This voltage drop can be detected using an Op-Amp (operational Amplifier **LM358**).

You will have to adjust the variable resistor (POT.) R8 so the the voltage at the positive input of the Op-Amp (pin No. 5) would be somewhere near 1.6 Volt. if you understand the functioning of Op-Amps, you will notice that the output will go High when the volt at the cathode of D1 drops under 1.6. So the output will be High when IR light is detected, which is the purpose of the receiver.

If the +ve input's voltage is higher than the -ve input's voltage, the output goes High (5v, given the supply voltage in the schematic), otherwise, if the +ve input's voltage is lower than the -ve input's voltage, then the output of the Op-Amp goes to Low (0V). It doesn't matter how big is the difference between the **+ve** and **-ve** inputs, even a 0.0001 volts difference will be detected, and the the output will swing to 0v or 5v according to which input has a higher voltage.

Gas Detector Sensor:

Gas detectors are generally housed in compact, disk-shaped plastic enclosures measuring approximately 150 millimeters in diameter and 25 millimeters in thickness. Most modern smoke detectors operate using one of two primary detection methods: **optical (photoelectric)** detection or **ionization** (physical process). Some advanced models combine both techniques to enhance sensitivity and reduce false alarms.

In large commercial, industrial, and multi-story residential buildings, smoke detectors are typically integrated into centralized fire alarm systems and supported by battery backup power. In contrast, smoke alarms installed in single-family homes are often powered solely by disposable batteries, offering a simple and cost-effective solution for individual households.

Soil Moisture Sensor

Soil moisture sensors are specialized devices used to measure the volumetric water content in soil. Unlike traditional gravimetric methods, which require extracting, drying, and weighing soil samples, these sensors provide indirect, real-time measurements by detecting changes in various soil properties that correlate with moisture levels.

Common measurement principles employed by soil moisture sensors include:

- **Dielectric Constant (Permittivity)**: Water has a significantly higher dielectric constant than soil particles or air. Sensors measure variations in the soil's dielectric properties to estimate moisture content.
- **Electrical Resistance**: As soil moisture increases, its electrical conductivity improves. Resistance-based sensors use this relationship to infer water content.
- **Neutron Interaction**: Neutron probes detect hydrogen atoms, which are abundant in water molecules, to determine moisture levels.

Because the relationship between the measured property and actual moisture content can vary depending on factors such as soil type, temperature, and electrical conductivity, proper calibration is essential for accurate readings.

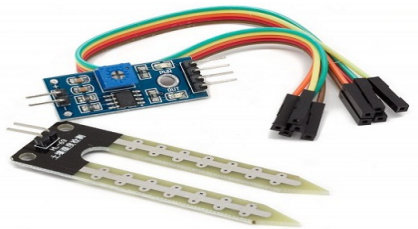
In remote sensing applications, reflected microwave radiation is influenced by both surface and subsurface soil moisture. This technique is widely used in agriculture and hydrology for large-scale environmental monitoring.

Sensor Pin Configuration (FC-28 Soil Moisture Sensor)

The FC-28 soil moisture sensor module features four pins:

- **VCC**: Power supply pin.
- **A0**: Analog output pin, providing continuous moisture level readings.
- **D0**: Digital output pin, indicating moisture status relative to a threshold.
- **GND**: Ground pin.

The module also includes an onboard potentiometer for adjusting the threshold value used by the comparator. An indicator LED turns on or off depending on whether the moisture level exceeds the set threshold.



soil-moisture-sensor

Working Principle

The FC-28 sensor operates on the principle of capacitance, measuring changes in the dielectric permittivity of the soil caused by varying water content. When the sensor probes are inserted into the soil, the device evaluates the capacitance and reports the moisture status as a percentage value.

This sensor is widely used in experimental and research applications across multiple disciplines, including environmental science, agricultural science, biology, soil science, botany, and horticulture.

Software Description

Arduino IDE compiler:

Arduino is an open-deliver electronics platform based mostly on smooth-to-use hardware and software utility. Arduino boards can observe inputs - slight on a sensor, a finger on a button, or a Twitter message - and flip it into an output - activating a motor, turning on an LED, publishing a few components online. You could tell your board what to do by sending a hard and fast of commands to the microcontroller at the board. To do so that you use the Arduino programming language (based totally mostly on Wiring), and the Arduino software (IDE), based on Processing.

Over the years Arduino has been the brain of lots of obligations, from regular gadgets to complex medical gadgets. A worldwide community of makers - college students, hobbyists, artists, programmers, and specialists - has collected spherical this open-deliver platform, their contributions have brought as much as a terrific amount of available know-how that can be of terrific assist to novices and experts alike.

Arduino has become born on the Ivrea interaction format Institute as a clean tool for instant prototyping, geared towards university college students without a historic past in electronics and programming. As quickly as it reached a miles wider community, the Arduino board started converting to conform to new dreams and traumatic situations, differentiating its provide from smooth eight-bit boards to merchandise for IoT

Programs, wearable, three-d printing, and embedded environments. All Arduino boards are without a doubt open-deliver, empowering clients to assemble them independently and ultimately adapt them to their unique dreams. The software program, too, is open-supply, and its miles growing thru the contributions of customers globally.

The advantages of the Arduino IDE utility are

1. much less steeply-priced
2. The clean smooth programming surroundings
3. Extensible software program application utility and hardware

8. Future Works

The proposed system has strong potential for further development and integration with emerging technologies. Future enhancements may include:

- Integration of Artificial Intelligence (AI) and Machine Learning for predictive maintenance and blockage forecasting.
- Addition of more advanced sensors for monitoring parameters such as pH level, toxic gas concentration, and flow rate.
- Development of a mobile application with real-time dashboards, historical data analysis, and automated complaint registration.
- Integration with smart city platforms for centralized urban infrastructure management.
- Incorporation of solar-powered sensor nodes for sustainable, long-term deployment in remote areas.
- Use of advanced communication technologies such as LoRaWAN or NB-IoT for improved coverage and reduced power consumption.
- Expansion to support large-scale municipal deployments with centralized cloud-based analytics and decision support systems.

9. Conclusion

Underground infrastructure monitoring presents significant challenges due to limited accessibility and the difficulty of real-time assessment. This project proposes an intelligent solution for effective monitoring and management of underground drainage systems. The system enables real-time identification and tracking of drainage conditions and manhole status using Internet of Things (IoT) technology.

Key parameters such as water level, flow rate, temperature, and the presence of toxic gases are continuously monitored by strategically deployed sensors. The collected data is transmitted wirelessly and updated on the internet, allowing concerned authorities to access real-time information from anywhere. This capability enables prompt decision-making and timely corrective actions whenever abnormal conditions are detected.

By providing continuous remote monitoring, the system significantly reduces the need for frequent physical inspections of manholes, thereby minimizing unnecessary field visits and associated risks. Regular updates on the internet also help maintain systematic drainage maintenance schedules, ultimately preventing potential hazards such as overflows, waterlogging, and environmental contamination.

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