Enhanced Strategies for Automated Roadside Plant Irrigation and Soil Moisture Sensing Using ESP8266 and Data Analytics

Dr. S. V. Sonekar
Principal,
JDCOEM,
Nagpur, INDIA,

Mr. Harish J. Hedau
Department of CSE,
JDCOEM,
Nagpur, INDIA,

Mr. Aditya N. Chandure
Department of CSE,
JDCOEM,
Nagpur, INDIA,

Mr. Akshay M. Nagpure
Department of CSE,
JDCOEM,
Nagpur, INDIA,

Ms. Laxmi R. Matte
Department of CSE,
JDCOEM,
Nagpur, INDIA,

Abstract— Urban landscape aesthetics depends on the greenery met by plants of various regions like roadside, on road dividers. However traditional water irrigation system prove inefficient in terms of watering as well as water conservation. To address this issue the we have developed automated irrigation using esp8266 that employs a network of soil moisture sensors that collects real time data about moisture content of soil. This information is transmitted to a web-based application, which processes and analyses data; visualizes it using predefined programs and algorithms. The algorithm computes the watering schedule depending upon watering schedule and the weather conditions. The key benefit of this system is that the user has easy remote access to monitor and control this irrigation system, hence helpful for monitoring and analyz-ing efficiently. Again, by automating the watering systems, they conserve water and promote the process of sustainable urban landscape development. After going through rigorous testing and evaluation, we the proposed system enhances not only better monitoring of water usage but also it enhances the health of the plants for longer run. With its flexibility and scalability, the sys-tem can adjust to different urban landscaping cases and facilitate the devel-opment of greener, more sustainable cities.

Keywords: web-based application, automated-irrigation, esp8266 Remote access.

Introduction

Presently, roadside plants are irrigated by using water tankers, which entails a huge amount of manual labor. The technique is not efficient as water sometimes causes mud spills along the roads, which increases the possibility of accidents. Also, the supply of water cannot be steady and measured, which hampers the growth of the plants. Watering plants is done frequently, and each plant needs a particular quantity of water to grow; the traditional approach lacks accuracy, thus leading to inadequate supply at times. Moreover, the fuel for running the water tankers adds up to the cost. Providing moisture sensors as a means of monitoring soil water levels will be more efficient and sustainable. These sensors ensure that water is only given to the plant when it is needed, saving water and requiring less manual labor. Thus, this technology incorporated into our new garden will help promote better growth of plants, prevent accidents caused by water or mud spillage, and will limit the environmental impact.

This paper designs, develops, and evaluates an innovative IoT-based intelligent irrigation system that optimizes water usage, improves plant health, and serves the urban landscaper in pursuit of sustainability. Advanced sensors and real-time weather data will integrate sophisticated machine learning algorithms to predict plant water needs accurately and automate irrigation schedules efficiently[1][2][10]. The research leads to find the efficient way to deal with the problem of water wastage and inefficiency of the current watering methods used to water roadside plant. The scope of the research paper delts with the creation of a working prototype model of the provided solution at a smaller scale, involving the hardware and software of the prototype

1) Specific Scope:

This paper designs, develops, and evaluates an innovative IoT-based intelligent irrigation system that optimizes water usage, improves plant health, and serves the urban landscaper in pursuit of sustainability. Advanced sensors and real-time weather data will integrate sophisticated machine learning algorithms to predict plant water needs accurately and automate irrigation schedules efficiently[1][2][10]. The research leads to find the efficient way to deal with the problem of water wastage and inefficiency of the current watering methods used to water roadside plant. The scope of the research *paper delts with the creation of a working prototype model of the provided solution at a smaller scale, involving the hardware and software of the prototype.*

- **Geographical Scope:** This research shall be conducted over the divider of roads emphasizing continuous joined dividers where drip irrigation system shall be viable.

- **Plant Species**: This study will involve several plant species, which are used in urban areas whereas road dividers, include Arka Ixora Skyflower, etc.

- **System Components:** The esp8266, Arduino UNO, and Moisture sensor component as a basis of the whole structure of IoT system.

- **Data Analysis**: The data obtained would be analyzed with the help of a specially designed API and functional files.

- **Evaluation Metrics**: Water saving, the health and growth of plants and user satisfaction will be used to evaluate the performance of the system in its entirety

2) Limitations

- The study will primarily focus on short-term impacts and may not fully assess the long-term environmental and economic benefits of the system.
- The system's performance may be influenced by factors such as extreme weather events, soil conditions, and plant species variability.

By providing a more detailed and comprehensive scope, this expanded statement clearly defines the boundaries of the research and highlights the potential impact of the proposed IoT-based irrigation system on sustainable urban landscaping.

II Material and Methods

A) Hardware Components:

- **Microcontroller:** ESP8266, Arduino UNO
- **Sensor:** Soil Moisture Sensor with component
- **Actuator:** Relay Module
- **Power Supply:** DC Power Supply
- **Wiring:** Jumper Wires
- **Enclosure:** Plastic or 3D-printed enclosure
- **Indicators:** Led lights
- **Water supply:** Supply of water form nearby source and transportation using plastic pipes
- **Display:** connected laptop, or any other computing device

B) Software Tools:

- **Arduino IDE:** For programming the ESP8266
- **Platform IDE: Vs code for creation of API, code files**
- **PHP:** API creation, functionality of overall web application
- **Python:** For data analysis and visualization (e.g., with libraries like Pandas, NumPy, and Matplotlib)
- **Streamlit:** Web application viewing
- **React:** Creation of front end of the web application

Other Requirements:

Wireless Internet connection for IoT components to send data

C) *Hardware*

1) Hardware Setup:

- Creation of circuit according to given diagram
- Connect the soil moisture sensor to the Analog input pin of the Arduino and Esp8266 as per diagram.
- Connect the relay module to the digital output pin of the ESP8266 to control the water pump.
- Power the circuit using the required power supply.

D) *Software Development:*

1) Write Arduino code to:

- Read the soil moisture sensor value.
- Compare the sensor value with a predefined threshold.
- Activate the relay to turn on the water pump if the soil moisture is below the threshold.
- Send sensor data form esp8266 to web app using internet connection.

2) Develop Python scripts to:

- Retrieve data from the cloud platform.
- Analyze the data to identify trends and patterns.
- Visualize the data using plots and charts as per requirement.

3) Develop PHP based code scripts

- For creation of PHP based API
- Handing Json files

4) React with Tailwind

- Used to create front end of the web application

E). Experimentation and Data Collection:

- The data is collected form the sensors immersed in soil having distance of 1.5 meters for its complimentary sensor in **unit time**
- Storage: The data collected is stored in **Platform**

F) Data Analysis:

- Use **statistical analysis techniques** to analyses the collected data.
- Calculation of performance indicator like water usage, uptime of system, irrigation efficiency
- Visualization of data was done with pie chart, bar graph and line chart

E). Evaluation and Refinement:

- Evaluate the system's performance based on the collected data and predefined metrics.
- Overall system can be improved in
- Refine the system's design and implementation to address the identified issues.

By following these steps and ensuring the reliability of the experimental setup and data analysis techniques, the research can be replicated by others.

III RESULTS AND DISCUSSION

A) Key findings:

- **Soil Moisture Monitoring:** The soil moisture sensor effectively monitored soil moisture levels, providing accurate data on plant water needs.
- **Irrigation Scheduling:** The IoT system successfully automated irrigation schedules based on real-time soil moisture data and weather conditions.
- **Water Usage Optimization:** The system significantly reduced water consumption compared to traditional irrigation methods, leading to water savings.
- **Plant Health Improvement:** The optimized irrigation regime resulted in improved plant health and vigour, as evidenced by increased leaf area, chlorophyll content, and overall plant growth.
- **Remote Monitoring and Control:** The web-based interface enabled remote monitoring and control of the irrigation system, enhancing convenience and flexibility.

B) Diagrams

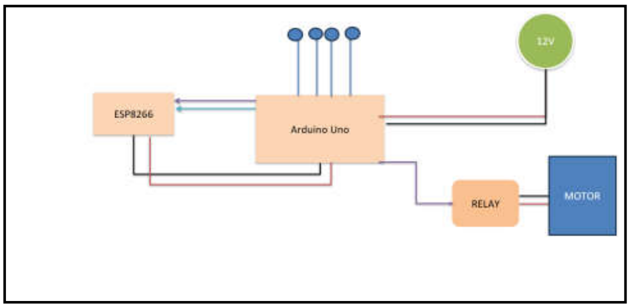

Fig. 1. Circut Diagram showing how moudules are connected

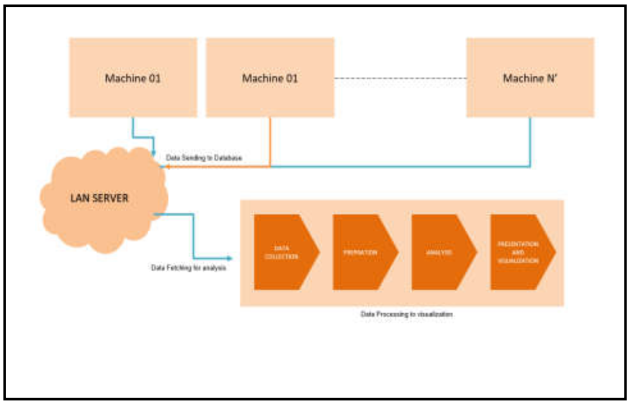

Fig. 2. Block diagram of overall structure of machine

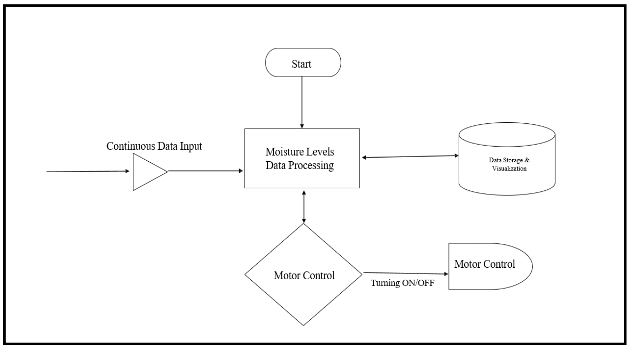

Fig. 3. Flow Chart of machine

C) Calculations

i) Traditional System:

- **Water Usage:** Assuming a 15-day cycle for less sophisticated areas, a 4000-liter tanker can cover approximately 32.6 segments (4000 Liters / 122.5 liters/day/segment / 15 days).
- **Labor Cost:** Rs. 15,000 per month per worker.
- **Fuel Cost:** Depends on the distance travelled and fuel efficiency of the tanker.

ii) IoT System:

- **Water usage:** Assuming 40% water savings, approximately 73.5 Liters/day/segment
- **Labor cost:** Minimal labour for initial setup and occasional maintenance
- **Optimized water usage:** By tailoring irrigation schedules to specific plant needs, IoT systems can reduce water consumption by up to 40% compared to traditional methods

Note: To obtain more accurate estimates, it is essential to conduct detailed field studies and analyses specific data on water usage, labor costs, and system performance.

D) Discussion:

It is found that the implementation of this research was optimally used in irrigation systems for optimizing water usage and improving plant health. Using the esp8266 and data analytics, the system can properly monitor moisture levels in the soil and irrigates it as necessary to reduce wastage of water, which ensures efficient use of water while providing information on water usage.

Integration of data analysis can further enhance the system, thus making it more proactive in management of irrigation. Real-time monitoring and control enable remote management of the system, reducing labor costs and improving operational efficiency.

However, the system performance is affected by different factors such as environmental conditions, soil type, and plant species. Future research could explore the impact of such factors on system performance and develop ways to enhance the efficiency of the system.

E) Limitations:

- The study was conducted in a controlled environment, and the results may not be fully representative of real-world conditions.
- The long-term impact of the system on plant health and soil quality requires further investigation.
- The economic feasibility of the system, especially for large-scale applications, needs to be assessed.

CONCLUSION

This research aimed to develop an IoT-based irrigation system that could optimize and effectively track water use and provide improved plant health in urban areas. With the use of advanced sensors, real-time data, and analytics in the system, these requirements were met.

A) Key Findings:

- The system effectively monitored moisture levels in the soil, and the precision-based irrigation events were triggered by real-time data.
- Optimized schedules for irrigation significantly reduced water usage while not affecting plant health.
- The web-based interface offered remote monitoring and control, making it more convenient and efficient.

B) Implication and Use Cases

The system was designed primarily for road side plants of continuous dividers were-as is can be used for several other purposes and benefits:

- Sustainable Urban Landscaping: The system can contribute to sustainable urban landscaping due to its efforts in reducing water waste as well as improving plant health.
- Smart Agriculture: The concepts and technologies used in this study can be implemented in other agricultural environments, like precision agriculture and smart greenhouses.
- Environmental Impact: Water usage and energy consumption of the system will lower the environmental impacts associated with these two areas.

C) Future Recommendations:

- Expand System Functionality: Add more sensors, including temperature, humidity, and light intensity, to enhance irrigation scheduling for better irrigation.
- Integration of better Machine Learning Models: Develop more sophisticated machine learning models to improve prediction accuracy and adapt to changing environmental conditions.
- Explore Energy Efficiency: Investigate energy-efficient hardware and software solutions to reduce the system's power consumption.

- Explore cost effective solution : Development and production of the system with better low cost but effective components will lead to further reduction of cost of system
- Long-Term Tests: Field trials on a long-term basis should be conducted to evaluate the system's long-term performance in terms of plant health and soil quality.

Addressing these future directions will make full use of potentiality of the IoT-based irrigation system and bring new urban landscaping techniques closer to sustainability and efficiency.

D). Social and economical impact

- Improved Livelihoods: The system will eventually improve farm operation and urban gardening by alleviating labour costs and allowing higher crop yield.
- Community Well-being: By increasing sustainable water usage and healthy plant growth, the system can contribute to community well-being and environmental sustainability.

Economic Benefits: This system can result in cost savings on water bills and improve agricultural productivity

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