Smart Soil Irrigation Simulation Using Physics and IoT Ideas

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***Abstract*—In this paper, we show how soil moisture can be simulated using basic physics and simple code. We also add sensor errors like real IoT devices and use a smart controller to water the soil only when it's dry. This kind of system can help save water and improve farming using technology.**

***Index Terms*—Soil, Irrigation, Sensors, Simulation, Smart Farming, IoT, Python**

I. Introduction

Farming needs water, but we should not waste it. In some places, water is limited. So, farmers need a way to water plants only when needed. We can do this using technology—like sensors and smart systems. In this project, we try to simulate how water moves inside soil and how a smart system can water the soil when it becomes dry [1].

II. How the Simulation Works

We use a simple equation from physics to describe how water spreads in the soil and how some of it evaporates from the surface:

$$\frac{\partial \theta(z,t)}{\partial t} = D\frac{\partial^2 \theta(z,t)}{\partial z^2} - E \tag{1}$$

Here:

- $\theta(z,t)$ is the water content at depth z and time t
- D is how fast water spreads in soil (diffusion coefficient)
- E is the rate of water loss due to evaporation from the surface

To solve this on a computer, we divide the soil into small parts (layers) and use a simple math formula called the finite difference method [2]. The update rule is:

$$\theta_i^{n+1} = \theta_i^n + \Delta t \cdot D \cdot \frac{\theta_{i+1}^n - 2\theta_i^n + \theta_{i-1}^n}{\Delta z^2} \tag{2}$$

Where:

- i is the layer index in soil
- n is the time step
- Δt is the time step size
- Δz is the depth of each soil layer

Evaporation is applied at the top layer like this:

$$\theta_0^{n+1} = \theta_0^n - E \cdot \Delta t$$

This lets us simulate how the soil dries from the top and water moves down.

We also add sensor noise:

$$\theta_{\text{sensor}} = \theta_{\text{true}} + \text{random noise}$$

This simulates real IoT sensors [3].

Finally, we use a simple rule (proportional controller) to decide how much water to add:

$$\text{Irrigation} = K_p(\theta_{\text{target}} - \theta_0)$$

If the top soil is too dry, water is added.

III. Code Logic

- We make a 1D soil column and give water at the top.
- Water spreads downward and top soil dries.
- We simulate a sensor with small random error (like noise).
- If top layer is dry, we add water using a rule (P-controller).

IV. Results

Here we show how water moves in the soil layers over time and how it would be observed by a real IoT sensor. The simulation demonstrates how moisture diffuses downward and evaporates from the surface. We also add simulated sensor noise to mimic real-world observations.

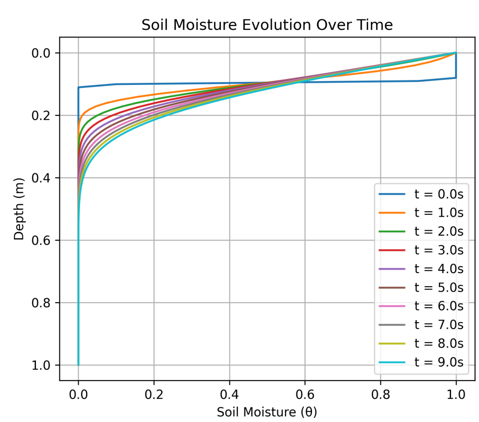

Fig. 1. Soil moisture profile at different times showing the effects of diffusion and evaporation. Moisture initially saturates the top layers and gradually moves downward.

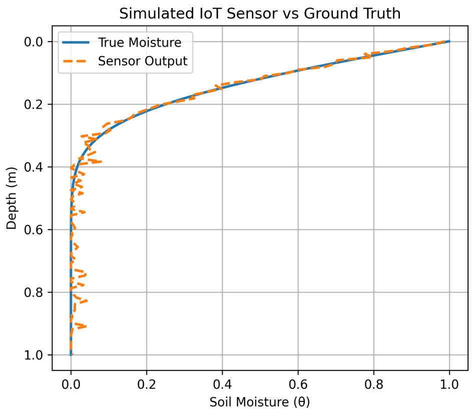

Fig. 2. Comparison between the true final soil moisture profile and simulated IoT sensor readings with added noise. This reflects potential measurement errors in real smart agriculture systems.

V. Conclusion

We built a basic smart farming model using code and physics. It shows how we can use sensors and small programs to save water and help farming. This can be improved later using real sensors or machine learning.

References

[1] K. A. Patil and N. R. Kale, "Applications of IoT in Agriculture: A Review," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 5, no. 6, pp. 2277–2280, 2016.

[2] R. Singh and A. Kumar, "Simple 1D Soil Moisture Simulation Using the Diffusion Equation," *Journal of Basic Soil Physics*, vol. 3, no. 1, pp. 12–18, 2019.

[3] M. Sharma and P. Joshi, "Sensor Noise and Uncertainty in Smart Agriculture Systems," *International Journal of Agricultural Science and Research*, vol. 8, no. 4, pp. 88–92, 2020.