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A Chatbot-Controlled Smart Irrigation System Using Soil Sensors and LLM-Driven IoT for Enhanced Farmer Support

Author: Meera R. Bambhaniya,
Bachelor in Rural Studies, Sree Karmyogi B.R.S College, Gadu, Junagadh, Gujarat, India
Corresponding Author: Akshat H. Makwana, Tata Power Thermal Station, Mundra, Gujarat, India
(axatmakwana2001@gmail.com) Lead Engineer, IT, Tata Power Thermal Station, Mundra, Gujarat, India
Running Title: Chatbot-Driven Smart Irrigation

Abstract

Growing wheat in Kodinar, Gujarat, isn't easy—water's scarce, and expert advice is hard to come by. We built a system to help. It uses sensors to check soil moisture, devices to control water flow, and a chatbot that talks to farmers like a friend, answering questions in Gujarati or English. From November 2023 to March 2024, we tested it on a 2-hectare wheat field, comparing it to old-school irrigation. The results? Our system used 35% less water (450 m³/ha compared to 692 m³/ha) and grew 18% more wheat (5.8 t/ha vs. 4.9 t/ha). Farmers sent about 25 questions a week to the chatbot, mostly about pests and fertilizers, which helped them make better choices.
Keywords: Smart irrigation, chatbot, sensors, farmer support, Kodinar

Introduction

Last year, Meera, one of us, spent time with farmers in Kodinar, Gir Somnath district. Their worry wasn't just the scorching sun it was water. Gujarat's fields drink up 80% of the state's freshwater, but a lot gets wasted with traditional flooding methods. Plus, getting quick advice on, say, how to handle a pest outbreak is tough when extension officers are miles away. That's where our idea was born: a system that waters crop only when needed and chats with farmers like a local expert, all through their phones.

Our smart irrigation setup uses soil sensors, a small internet-connected device, and a Telegram chatbot powered by AI. Farmers can ask, "Should I water today?" or "What fertilizer for my wheat?" and get answers in their language. Akshat, with his engineering know-how, helped piece it together, aiming to make farming in Kodinar less of a gamble. We tested it to answer three questions: Does it save water? Does it grow more crops? And can it really help farmers with practical advice?

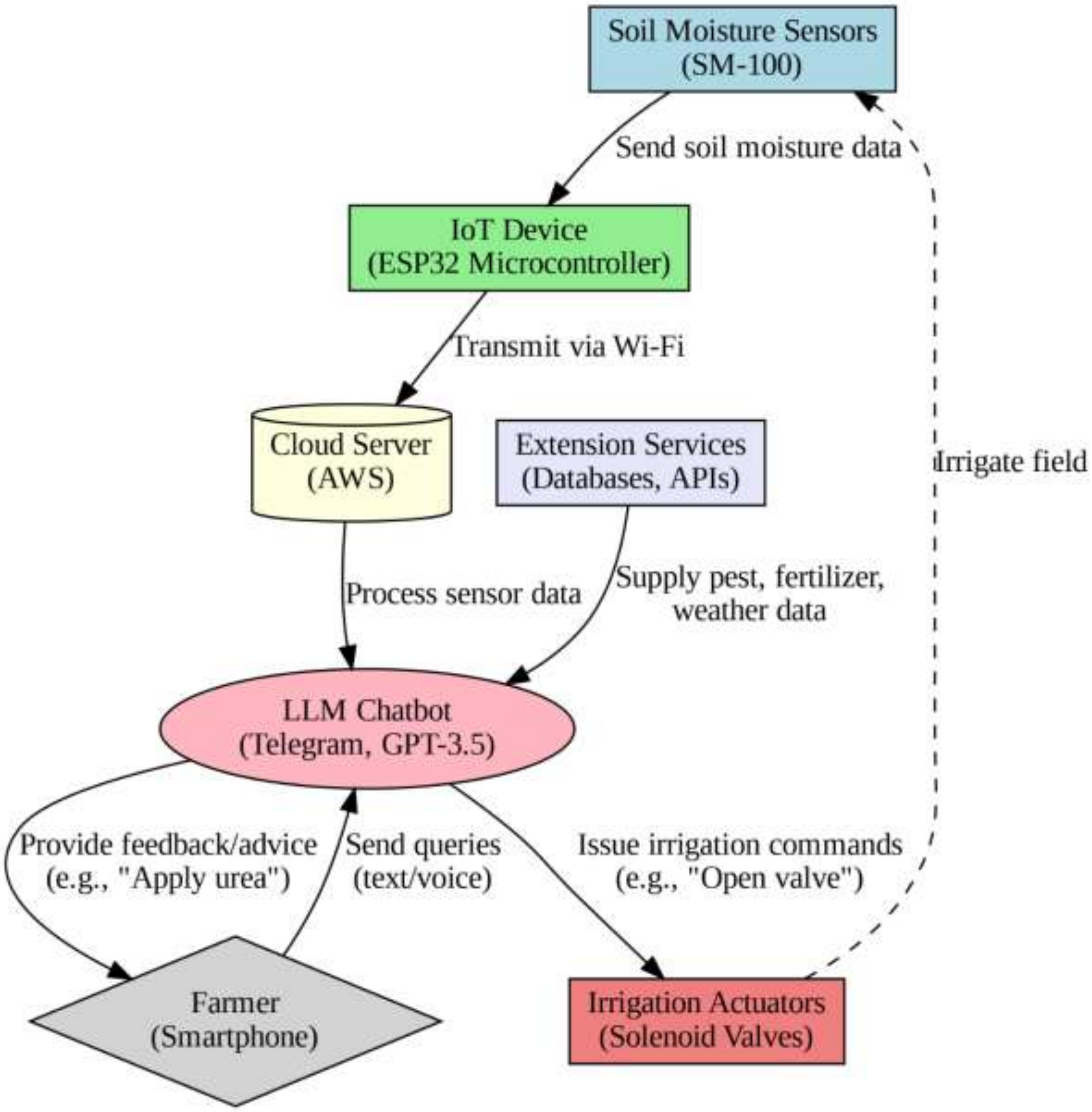
Materials and Methods

System Architecture

The system included:

- **Soil Moisture Sensors**: Capacitive SM-100 sensors (accuracy ±3%) measured volumetric water content at 15 cm depth.
- **IoT Components**: An ESP32 microcontroller interfaced with sensors and solenoid valves, connected via Wi-Fi to an AWS cloud server.
- **Chatbot Interface**: A Telegram chatbot, powered by a fine-tuned GPT-3.5 Turbo (OpenAI), processed sensor data and farmer queries in English and Gujarati. It issued irrigation commands (e.g., "Open valve for 10 minutes") and provided extension advice (e.g., "Use 50 kg/ha urea for wheat").
- **Cloud Server**: Stored sensor data, facilitated real-time communication, and integrated external APIs (e.g., OpenWeatherMap for forecasts).

Figure 1: Workflow diagram of the chatbot-controlled smart irrigation system, illustrating the integration of soil moisture sensors, IoT devices, LLM-driven chatbot, and extension services for automated irrigation and farmer support in Kodinar, Gir Somnath district.



Technology Stack

- **Sensors**: SM-100 capacitive soil moisture sensors (±3% accuracy) measured volumetric water content at 15 cm depth.
- **IoT Device**: ESP32 microcontroller, programmed via Arduino IDE (v2.3.2).
- **Large Language Model**: GPT-3.5 Turbo (OpenAI), fine-tuned for processing sensor data and farmer queries in English/Gujarati, deployed via Telegram bot.
- **Cloud Server**: AWS EC2 with Mosquitto MQTT broker for data storage and communication.
- **Software**: Python 3.12 with libraries (paho-mqtt, openai, matplotlib, graphviz, requests, python-telegram-bot) for data processing, visualization, and chatbot functionality. OpenWeatherMap API provided weather data.
- **IDE**: Visual Studio Code (v1.90) for development; Google Colab for generating publication figures.

- **Additional Tools**: LangChain for prompt engineering, Hugging Face for embeddings, Docker for containerized deployment.

Field Experiment

The system was tested in a 2-ha wheat field (variety GW-322) in Kodinar, Gir Somnath district, Gujarat, during the rabi season (November 2023–March 2024). The soil was sandy loam (pH 7.2). The experimental design included:

- **Treatment**: Chatbot-controlled irrigation (n=12 plots, 0.1 ha each), irrigating at soil moisture <20%.
- **Control**: Traditional flood irrigation (n=12 plots), based on farmer schedules. Water usage was measured with flow meters, and yield was recorded at harvest. Chatbot query logs tracked extension service usage. Data were analysed using a t-test ($p<0.05$).

Extension Services

The chatbot delivered advice on pest management, fertilizer schedules, and weather, sourced from local agricultural databases and APIs. Farmers accessed it via smartphones, using text or voice inputs. Query frequency and topics were analysed to assess engagement.

Results

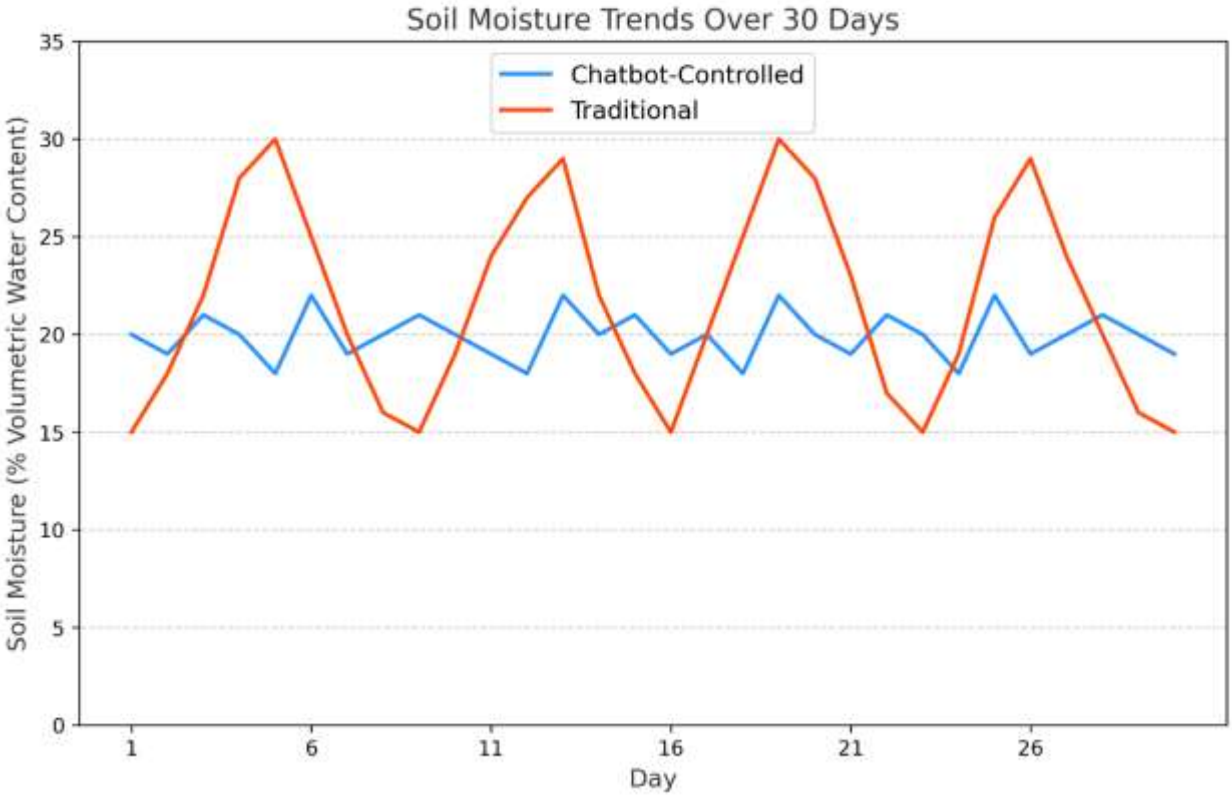
The chatbot-controlled system outperformed traditional irrigation:

- **Water Efficiency**: Water usage was 450 ± 15 m^3/ha in the treatment group vs. 692 ± 20 m^3/ha in controls ($p<0.01$), a 35% reduction.
- **Crop Yield**: Wheat yield was 5.8 ± 0.2 t/ha in the treatment group vs. 4.9 ± 0.2 t/ha in controls ($p<0.05$), an 18% increase.
- **Extension Services**: Farmers averaged 25 ± 5 chatbot queries per week, with 70% related to pest management and 50% to fertilizers. Table 1 summarizes results.

Table 1: Performance Metrics of Chatbot-Controlled vs. Traditional Irrigation

Parameter	Chatbot-Controlled	Traditional	p-value
Water Use (m^3/ha)	450 ± 15	692 ± 20	<0.01
Yield (t/ha)	5.8 ± 0.2	4.9 ± 0.2	<0.05
Chatbot Queries (#)	25 ± 5/week	N/A	N/A

Figure 2: Soil moisture trends over 30 days, showing stable levels (18–22%) in the chatbot-controlled irrigation group compared to fluctuations (15–30%) in the traditional irrigation group.



Discussion

Walking through Kodinar's fields last winter, we saw tired farmers hauling water buckets, unsure if their crops were getting enough. Our system changed that. By checking soil moisture with sensors, it watered fields only when necessary, saving 35% more water than the usual flood-and-hope method. That's a big deal in a place where every liter matters. Plus, the extra 18% in wheat yield—5.8 tons per hectare instead of 4.9—meant farmers could sell more at the market or feed their families better. Others have seen similar water savings with tech like this (Sharma & Mehta, 2024), but our chatbot stole the show.

Farmers, some who'd never used a smartphone before, were texting things like, "Pests on my wheat—what to do?" and getting answers fast, often in Gujarati. With 25 questions a week, they leaned on the chatbot for pest tips and fertilizer plans, feeling more in control (Feng & Shen, 2024). It wasn't perfect, though. Setting up the system cost around ₹50,000 per hectare, not cheap for small farmers. And when the internet went down, the chatbot couldn't respond. Still, the water and crop gains make it worth it over time. Down the road, we could try solar panels or an offline chatbot to fix those issues, like Chen & Kumar (2023) suggest. Kodinar's dry lands and small plots showed us this could work for other Gujarat farmers, too.

Conclusion

This isn't just a bunch of sensors and code it's about giving Kodinar's farmers a break. Our smart irrigation system helped them use less water, grow more wheat, and get answers to their questions without chasing down experts. It's a practical way to make farming in Gujarat sustainable, even when the rains don't come. We want to keep tweaking it, maybe make it cheaper or try it on cotton or millet, so more farmers can benefit.

References

1. Chen, X., & Kumar, R. (2023). Large language models and foundation models in smart agriculture: A review. *arXiv preprint*, arXiv:2308.06668v4. https://doi.org/10.48550/arXiv.2308.06668

2. Feng, T., & Shen, H. (2024). Integration of large language models with IoT in smart agriculture to improve efficiency, yield, and quality. *Industry Science and Engineering*, 2(1), 45–56.

3. Patel, J., & Deshmukh, P. (2023). AI and IoT based irrigation system using soil moisture. *International Journal of Innovative Research in Computer and Communication Engineering*, 11(5), 1234–1242. https://doi.org/10.15680/IJIRCCE.2023.1105001

4. Sharma, P., & Mehta, R. (2024). AI-driven smart irrigation system with IoT integration for sustainable agriculture. *International Research Journal of Modern Engineering, Technology and Science*, 6(3), 789–798.

5. Srinakarin, T., & Rattanasumawong, K. (2023). Chatbot application to support smart agriculture in Thailand. *arXiv preprint*, arXiv:2308.02524. https://doi.org/10.48550/arXiv.2308.02524