Smart Water Irrigation System

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SIT225 – Data Capture Technologies
Project: Smart Water Irrigation System
Assignment 9.1P: Use Case Study
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Introduction

Problem Statement:

- Water scarcity is a major problem across many areas in the globe
- Water management in agriculture is crucial in water-scarce countries
- More than 70% of the world fresh water is being used for these activities
- Global warming necessitates water adaptation measures for food production.
- Water management for irrigation is mostly being done by humans – generally in trial-and-error fashion leading to complex and inaccurate results - 30% of that water is wasted or misused.
- Commercial sensors for agricultural irrigation are expensive, but low-cost sensors are now available.
- Advances in Internet of Things (IoT) and Wireless Sensor Networks (WSN) technologies have facilitated affordable irrigation management systems.
- Utilization of sensors to monitor various parameters and wireless technologies to transmit real-time information along with automation allows for accurate use of water for irrigation.
- These technologies will not only saving the natural resource but also creating a more sustainable way of farming

Reference: IoT-Based Smart Irrigation Systems: An Overview on the Recent Trends on Sensors and IoT Systems for Irrigation in Precision Agriculture (García et al. 2021)

Objective:

To design a **smart irrigation system** for home based or small farms using sensors to monitors key environmental and weather parameters in real-time, transmits real time information to the irrigation system which, based on the specific crop's irrigation requirements issues commands to actuators that automatically regulate irrigation leading to optimal water usage

Literature Review

- **Existing Solutions:**

Study	Methodology	Data Sources	Limitations
Study 1 (Semananda et al. 2018)	Capillary irrigation	Container based sub-irrigation systems - capillary mats, ebb and flow systems, capillary wicks, and subirrigated planters (SIPs)	• Advanced technological usage - complicated and expensive. • Lack of consistent matting wetness in the capillary mat system, may lead to inconsistent substrate moisture content or insufficient supply of water to plants
Study 2 (Khaled et al. 2022)	Smart irrigation Technology systems	Control and management of irrigation systems from anywhere by providing access via smartphone or computer	• High power consumption, weak communication signals, low privacy on servers • Costs and payback periods vary depending on the number of variables • Lack of knowledge and understanding of farmers
Study 3 (Rivulus 2019)	A center pivot irrigation system	A pivot system consists of a lateral, stainless-steel pipeline mounted across adjacent, mobile truss structures that support the pipe. Flow rates and pressure regulators are utilized to create either a high-flow or low-flow system depending on water use needs	• Relatively very high initial investment • Might encourage plant disease • Under windy conditions, might provide poor water distribution uniformity • Cannot irrigate the whole field at once • High energy consumption

Designing a Typical Irrigation System

Designing a Typical Irrigation System:

- Identify and secure the source of water/ nearby water body
- Finalize the method of irrigation
- Design the layout to ensure coverage across the field
- Design the carrier pipelines to the farm to ensure controls as desired
- Finalize the parameters (viz. Environmental, weather, etc.) to be measured and transmitted
- Mode of communication (WIFI/RF)
- Design actuators to enable precise control over water distribution
- Design valves for water flow control.
- Develop databased for crop specific irrigation needs.
- Design control logic.

Table I.

Cost, Energy and Water Consumption, and Payback Periods of the Systems

Category	Traditional irrigation	Sprinkler irrigation	Drip irrigation	Pivot irrigation	Smart irrigation
Installation cost	Medium	Medium-high	Medium-high	High	Medium
Operating costs	Medium-high	Medium-high	Low-medium	Medium-high	Low-medium
Energy usage	High	High	Low	High	Low
Water loss	High	Medium	Low	Medium	Low
Payback period	Long	Medium-long	Medium-long	Medium-long	Medium-long

Key Inefficiencies in Existing Systems:

- Lack of Automation: Most systems require manual intervention or only partially automate the process.
- Water Wastage: Systems not responsive enough to avoid over-irrigation, especially during rains
- Power Supply: Most irrigation systems that do not have power grid/ require alternative source of power.
- Constraint Access hours: Many systems have constraint power access - receive power during odd time for limited hours
- Monitoring: Low frequency of monitoring - real-time monitoring has been surging as the costs decline.
- Sensors: Typical commercial sensors for agriculture irrigation systems are very expensive.
- Data Analytics: Use of historical data for prediction and optimization of water use.

Smart Irrigation System – Existing System

Existing Solution Analyzed:

IOT based smart irrigation system for home based organic garden by Karunakant, et al.(June 2018) International Journal of Pure and Applied Mathematics

Details of the System:

The solution analyzed supports the crop growth using data such as temperature, humidity, soil moisture, air moisture, etc. collected using sensors to provide valuable information for user decision making. It also supports the remote discovery and monitoring through the Internet of Things This Internet of Things based smart irrigation system results is efficient water management and remote access and better crop growth when compared to the conventional irrigation methods. (Refer schematic presented in the next page).

Short Coming Identified:

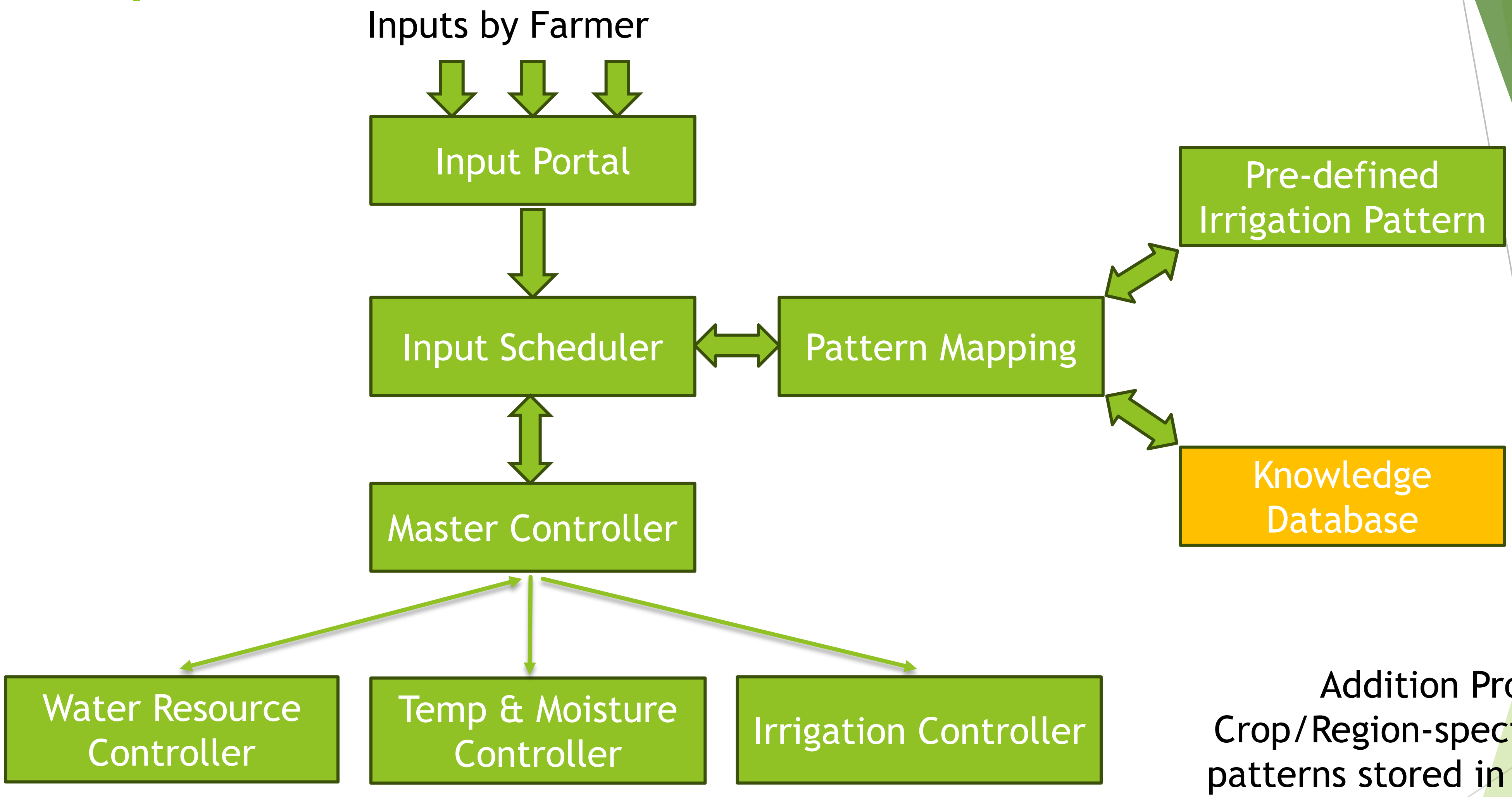
The proposed irrigation method is agnostic with reference to the type of crop. Some crops require more water or frequent watering as compared to other crops, Also, the system may need to cater to various types of crops in the same farm. A uniform pre-designed irrigation pattern may not be the optimal solution and may lead to over or under irrigation.

Proposed Improvement:

The project proposes to add plant-specific and region-specific irrigation patterns. The patterns would be developed in consultation with the agricultural experts. The patterns will be stored in a knowledge database which will be accessed by the pattern mapping system to send appropriate irrigation patterns for the relevant crops.

The solution is also useful for multiple type of crops in the same farm. Such farms will require separate irrigation controls along with separate actuators and sensors.

Proposed Schematic



Addition Proposed
Crop/Region-specific irrigation patterns stored in the database

Green: Schematic Proposed by Karunakant et al 2018
Orange: Addition proposed in this project

Proposed Methodology

- **Data Sources**:
  - **Soil Moisture Sensors**: To monitors soil moisture levels (4 sensors to cover different zones).
  - **Temp & Humidity Sensors**: To measures environmental temperature and humidity.
  - **Water Flow Sensors**: To track the amount of water & it's usage in real-time to prevent wastage.
  - **Rain Sensors**: To detect rainfall and avoid/halt irrigation when it rains.
  - **Irrigation Pattern**: Pre-defined or crop specific irrigation patterns, with control for multi zones.
- **Data Types**:
  - Soil moisture levels (%)
  - Environmental temperature (°C/°F)
  - Humidity (%)
  - Water flow (liters per minute)
- **Data Capture Protocol**:
  - Use **Arduino microcontroller** for collecting data from soil moisture, temperature, and humidity sensors.
  - Wireless communication through the ESP8266 Wi-Fi Module for real-time data transmission.
  - Collect & monitor real-time sensor data via **Arduino Cloud** and control the irrigation remotely.
- **Power Supply:**
  - Solar-powered system with a 50W solar panel, charge controller, and a 12V battery to ensure off-grid operation and power backup.
- **Data Logging and Storage**:
  - **Local Storage**: Store data on an SD card for backup and local access .
  - **Cloud Storage**: Use Arduino Cloud for real-time data logging and remote monitoring, with optional expansion to AWS IoT if scalability is needed.

Proposed Methodology – contd.

- **Monitoring Dashboard**:
  - Use a **Plotly Dash** to visualize moisture levels, temperature, humidity, water usage and irrigation pattern.
  - The dashboard provides real-time data, historical trends, decision making aids, provide alerts, and allows for automation or manual interventions with (automated and predictive responses).
- **Automation and Decision-Making**:
  - Use preset thresholds (e.g., soil moisture below 40%) to automatically trigger the irrigation system via solenoid valves.
  - Use **data analytics** to predict water needs based on historical data, soil conditions, and crop-specific requirements.
  - System avoids/halts irrigation if rainfall is detected by the rain sensor.
- **Communication and Alerts**:
  - Automated notifications via IFTTT or Zapier (email/SMS) when moisture levels fall below the set threshold or irrigation is turned on/off.
  - Automation triggers crop-specific irrigation patterns based on environmental conditions.
  - Notify through the dashboard and SMS if any irregularities are detected (e.g., a sudden drop in soil moisture).
- **Software and Cloud Services:**
  - **Arduino IDE:** For system programming and control.
  - **Arduino Cloud:** For real-time monitoring, data analytics, and automation.
  - **Plotly Dash:** Visualization of sensor data and historical trends.
  - **IFTTT/Zapier:** Automation for alerts and notifications.
- **Power Supply:**
  - Solar Panel (50W) for off-grid power and cost-effective long-term operation.
  - Charge Controller and Battery to ensure stable power even during low sunlight periods.

Budget and Development Plan

1. Budget Summary

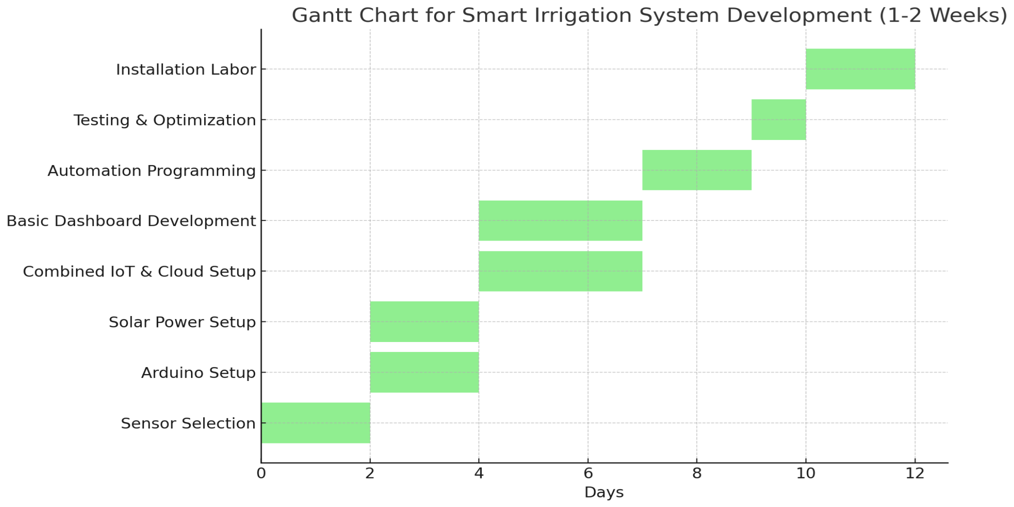
Component	Specification	Quantity	Unit Price (USD)	Total Cost (USD)
Arduino Uno	Microcontroller for data collection and control	1	$25	$25
ESP8266 Wi-Fi Module	Wireless communication for cloud connectivity	1	$7	$7
Soil Moisture Sensor	Capacitive sensor for soil moisture monitoring	4	$8	$32
DHT22 Temp & Humidity Sensor	Environmental monitoring sensor	2	$10	$20
Rain Sensor	Sensor to detect rainfall and stop irrigation	1	$5	$5
Water Flow Sensor	Measures water flow for optimization	1	$15	$15
Solenoid Valves	Controls water flow for different crop zones	4	$12	$48
Water Pump	Pump for irrigation control	1	$40	$40
SD Card & Module	Local data storage for sensor readings	1	$15	$15
Relay Modules	Control valves and pump	2	$8	$16
Solar Panel (50W)	For powering the irrigation system	1	$50	$50
Charge Controller	Manages solar power input to battery	1	$20	$20
12V Battery (20Ah)	Powers the system during cloudy days/night	1	$40	$40
DC-DC Converter	Regulates power from battery to components	1	$15	$15
Pipes & Fittings	Piping for irrigation (PVC or PE pipes)	20 meters	$2 per meter	$40
Miscellaneous	Wiring, enclosures, connectors, mounting kits	-	$25	$25
Labour	Workforce for Installation of the system	40 Hours	$20/Hr.	$800

2. Software & Cloud Services

Software	Specification	Cost (USD)	Notes
Arduino IDE	Open-source development environment	Free	-
Arduino Cloud	Cloud service for real-time monitoring	$6.99/month	Includes monitoring, automation, and alerts
Plotly Dash	Data visualization dashboard	Free	Free for small-scale projects
IFTTT/Zapier	Automation & notifications via SMS/email	Free or $5/month	Sends crop-specific irrigation alerts and triggers

3. Development Timeline

Task	Start Date	End Date	Duration (Days)	Estimated Hours
1. Sensor Selection	Day 1	Day 2	2	4
2. Arduino Setup	Day 3	Day 4	2	4
3. Solar Power Setup	Day 3	Day 4	2	4
4. Combined IoT & Cloud Setup	Day 5	Day 7	3	8
5. Basic Dashboard Development	Day 5	Day 7	3	6
6. Automation Programming	Day 8	Day 9	2	4
7. Testing & Optimization	Day 10	Day 10	1	4
8. Installation Labor	Day 11	Day 12	2	6
Total			**12 Days**	**40 Hours**



4. Scale and Application

- Designed for 0.25 to 0.5 acres (1,000-2,000 sqm)
- 4 irrigation zones with crop-specific controls
- Solar-powered for off-grid operation
- Ideal for small farms or home gardens

Summary:

Item	Cost (USD)
Total Hardware Cost	$413
Total Labor Cost	$800
Software & Cloud Services	$10/month(ongoing)

Ethical Considerations

Privacy & Security:

- Since the project is dealing with environmental data, the risk of privacy breaches is minimal. However, if expanding to include personal data (e.g., farm data), implementation of encryption for storage and secure communication recommended.
- Garcia et al. (2020) report the following list of security threats and managing risks: vulnerable software/code, privacy threats, cloning of things, malicious substitution of things, eavesdropping attacks, man-in-the-middle attack, firmware attacks, extraction of private information, routing attack, elevation of privilege, denial-of-service (DoS) attacks. Moreover, the study further stated emphasis on DoS attacks and the importance of protecting the irrigation system from DoS attacks or avoiding attackers from accessing the collected data or the system with the intention of damaging the crops.
- As cloud computing often goes hand in hand with IoT systems, threats to cloud services may compromise the IoT irrigation system as well. Flooding attacks and cloud malware injection are some of the attacks that can be intentionally executed to compromise the data and the performance of the cloud
- Ransomware is another security threat that could affect irrigation systems for agriculture - All the data regarding pesticides and the fertigation system could be encrypted until a ransom is paid.
- Blockchain is a new technique that is being applied to secure IoT systems, which allows secure data storage and communication. In agriculture, it is mostly utilized to secure the supply chain. Regarding IoT irrigation systems for agriculture, blockchain has been applied in to track and trace the information exchange of their proposed smart watering system.

Conclusion

Summary:

- The proposed smart irrigation system aims to optimize water usage through real-time environmental and soil data, crop specific patterns via knowledge database and automation.
- It uses a solar-powered design, making it suitable for off-grid applications and reducing energy costs.
- It integrates data analytics and historical trends to improve both immediate and long-term irrigation planning
- The solution provides real-time visibility and alerts via a dashboard, allowing farmers full control of irrigation processes.
- It addresses gaps in existing systems, including water wastage, manual labor, and lack of automation.
- It offers a cost-effective, scalable solution ideal for small to medium-sized farms.

Future Work:

- Design a modular, plug-and-play system to allow easy scaling for farms of different sizes and configurations.
- Integrate weather API data for real-time, dynamic irrigation adjustments based on upcoming weather patterns.
- Enhance scalability to handle larger farms by expanding the number of irrigation zones and improving communication protocols for longer distances.
- Investigate AI-based predictive analytics to optimize irrigation based on more advanced data trends, crop health, and soil conditions.
- Conduct detailed engineering and design studies followed by real-world pilot implementations in various farming environments.
- Explore the integration of drone-based farm monitoring for even more precise water use in large-scale agriculture.

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