AQUAFLOW: AN ARDUINO-POWERED SMART IRRIGATION SYSTEM FOR GUMAIN DAM

Katherine S. Baltazar, DON HONORIO VENTURA STATE UNIVERSITY
Kyla Q. Angeles, DON HONORIO VENTURA STATE UNIVERSITY
Vherwin Jaymes V. Clemente, DON HONORIO VENTURA STATE UNIVERSITY
Allen Dave D. Manongsong, DON HONORIO VENTURA STATE UNIVERSITY
John Herbert C. Santiago, DON HONORIO VENTURA STATE UNIVERSITY

ABSTRACT

The "AQUAFLOW" project endeavors to transform irrigation practices at Gumain Dam through an innovative smart irrigation system using Arduino technology. Termed "An Arduino-Powered Smart Irrigation System for Gumian Dam," this initiative integrates sensors, data processing techniques, and the NodeMCU ESP8266 microcontroller. Its goal is to optimize water usage and enhance irrigation efficiency in the surrounding agricultural fields. The research primarily focused on designing, developing, and implementing AquaFlow to minimize water wastage, continually monitor water levels, and create a user-friendly interface for farmers. Employing a descriptive quantitative research design, the study utilized the Rapid Application Development (RAD) approach for system development and testing. Through interviews and survey questionnaires, the research aimed to understand community needs, evaluate system effectiveness, and gauge user satisfaction. Conducted in Barangay San Pedro Floridablanca, Pampanga, the research specifically targets experienced farmers, utilizing purposive sampling techniques. This approach integrates ISO/IEC 25010 Software Quality Model constructs to assess system acceptability and excellence. The findings revealed the significant positive impact of AquaFlow on water conservation, crop productivity, and user contentment. It underscores the system's potential in fostering sustainable farming practices while effectively addressing water irrigation challenges. In alpha testing, the survey achieved a highest acceptability score of 3.8, signifying strong satisfaction, with an overall mean score of 3.68, indicating a positive response from participants. Beta testing attained a peak acceptability of 3.73, reflecting encouraging approval, with an overall mean score of 3.42, indicating a decent level of satisfaction. In the post-survey analysis, the highest functional suitability was noted at 3.64, emphasizing notable effectiveness.

***Keywords**: Smart Irrigation System, Arduino Technology, Blynk Application, IoT (Internet of Things), Water Flow Control, Water Level Monitoring.*

INTRODUCTION

In a world where water begins to threaten the ability to feed a growing population, the urgent need for innovative irrigation solutions becomes a call to action for sustainable agriculture. Water irrigation plays a pivotal role in the agricultural landscape of the Philippines, a country with a rich and diverse agricultural sector that sustains the livelihoods of millions of Filipinos. With its archipelagic geography and varying climatic conditions, the Philippines faces unique challenges and opportunities in the realm of water management for irrigation. Agriculture is a cornerstone of the Philippine economy, providing employment and sustenance to a significant portion of the population. The need for efficient water irrigation systems has become increasingly critical to enhance agricultural productivity and ensure food security. In this tropical archipelago, where the climate ranges from humid to semi-arid, effective water management is vital for optimizing crop yields and mitigating the impact of unpredictable weather patterns. Traditional irrigation methods like flood irrigation and sprinkler irrigation have proven to be inefficient, leading to water waste and crop damage. Also, the unpredictability of weather conditions has led to abnormal water levels. It limits the capacity of water reservoirs, further complicating the effectiveness and sustainability of the irrigation system. The obstruction caused by quarries blocking rivers hampers water flow, adversely affecting irrigation processes and agricultural productivity. Heavy rainfall exacerbates the situation by increasing the volume of irrigation water, making efficient water distribution a challenging task. Despite technological advancements, manual control of water flow through machinery remains prevalent, necessitating continuous human intervention that can be time-consuming and prone to errors.

To ensure optimal crop growth and prevent damage, maintaining appropriate water pressure becomes crucial for different crops. The closure of dams when farmers no longer require water often relies on manual intervention, leading to potential inefficiencies. Certain crops, such as rice, papaya, banana, eggplant, beans, corn, and cassava, are particularly vulnerable to damage or death when exposed to excessive water. Recognizing the importance of effective water resource management, the National Irrigation Administration (NIA) assumes a crucial role in monitoring and controlling water resources for irrigation purposes. Furthermore, manual monitoring of water flow involving local staff, including barangay tanods, kagawads, and barangay captains, is indispensable for successful irrigation management. Addressing these issues is vital for sustainable irrigation practices and securing our agricultural future. When it comes to watering their crops, farmers confront a common set of issues. Overwatering can result in saturated soil and root damage, whilst underwatering produces drought stress. unequal water distribution is a recurrent problem, frequently caused by errors or failures in system design, resulting in unequal plant growth. It is critical to keep irrigation equipment in good working condition. Sprinklers and drip emitters are quickly clogged and must be maintained on a regular basis to ensure a smooth water flow. Inefficiencies in system design contribute to water waste and insufficient coverage, worsening farmers' problems. Additional issues may occur for individuals who use smart irrigation systems using sensor technologies. Sensor malfunctions and the need for contingency plans in the event of power outages or technical breakdowns add layers of complexity to the already intricate task of effective crop watering. In essence, addressing these challenges requires a comprehensive approach, combining sound system design, regular maintenance practices, and strategic use of technology. Irrigation comes in many different ways which makes it a crucial component of agriculture, providing water to crops or flowers in areas where rainfall is insufficient or unreliable. With the increasing global demand for food and the impact of climate change on water resources, efficient irrigation practices are essential for ensuring sustainable agriculture. Development is the foundation of the economy in spite of money related movements (Kanade, Prasad 2021). Smart irrigation is an emerging technology that uses sensors and other devices to regulate the amount of water delivered to plants based on real-time data. In this capstone project, the proponents aimed to develop a smart irrigation system using Arduino, to optimize irrigation and reduce water waste

Project Context

In today's world, the problem of water scarcity is a crucial danger to sustainable agriculture and the capability to feed a growing population. Ineffective irrigation methods including sprinkler irrigation and flood irrigation can cause water waste and crop damage. Agriculture is a major contributor in the Brgy. San Pedro Floridablanca, Pampanga, where this capstone project was conducted, provides an important percentage of the local population. However, recent years have experienced an increase in the growth of agricultural production, limiting sustainability and economic progress. The difficulties in water management and irrigation increase the problem. Unpredictable weather, unusual water levels, restricted dam capacity, and water flow limitation due to quarries all interrupt the irrigation process, lowering the production of crops. Furthermore, manual handling of water flow through machinery remains common, causing inefficiencies and the necessity for continuous human intervention.

Maintaining sufficient water flow and establishing efficient distribution of water become essential factors in ensuring optimal crop growth and preventing crop damage. In addition, dams shut down when farmers no longer need water are usually manual resulting in substantial inefficiencies and water waste. Several crops, such as rice, papaya, banana, eggplant, beans, corn, and cassava, tend to be particularly vulnerable to damage or loss when exposed to excessive amounts of water. Recognizing the important role for effective water resource management highlights the importance of innovative and effective irrigation systems. This capstone project aimed to solve these issues through developing the AquaFlow smart irrigation system with Arduino technology. Through real-time data monitoring and management, the AquaFlow technology aims to enhance irrigation methods and reduce water waste. The system will control the amount of water supplied to crops through the use of sensors and other devices, ensuring that crops acquire the exact amount of water they need in various situations. This will reduce waste water, encourage sustainable water management techniques, and improve crop production.

The success of this study was determined by comparing the AquaFlow system's usage of water and yield of crops with the tradition irrigation methods such as flood irrigation or sprinkler irrigation. In addition, the economic and environmental benefits of the smart irrigation system were evaluated, including cost reductions in water usage and a possible impact on productivity of crops and overall agricultural sustainability. The AquaFlow smart irrigation system intends to contribute to sustainable agriculture, secure food production, and establish a path for a more secure and water-efficient future by solving the issues of water scarcity and inefficient irrigation methods.

Purpose and Description

The "AQUAFLOW" aimed to develop an innovative smart irrigation system using Arduino technology for Gumain Dam. Gumain Dam is a large-scale irrigation reservoir located in a region with limited water resources. The objective of the project was to optimize water usage and improve the efficiency of irrigation practices in the agricultural fields connected to the dam. The proposed system utilizes Arduino, an open-source electronics platform, to monitor and control the irrigation process. It incorporates sensors, actuators, and data processing techniques to achieve intelligent irrigation management. Aquaflow: An Arduino-Powered Smart Irrigation System for Gumian Dam has the following capabilities:

• Sensor Network: A network of sensors is deployed across to measure the level of the water in the field. These sensors provide valuable insights into the water requirements.
• Data Processing and Analysis: The collected sensor data is processed and analyzed using algorithms and software applications.
• Control Mechanism: The NodeMCU ESP8266 microcontroller, equipped with appropriate components that controls the irrigation process. It manages the flow of water from irrigation to the fields, ensuring efficient water delivery based on the water level data from the ultrasonic sensors.
• Communication and User Interface: The system incorporates wireless communication capabilities to transmit data between the sensor network, NodeMCU ESP8266 microcontroller, and a user interface from the Blynk App. The user interface can be a mobile application that allows farmers or irrigation managers to monitor the settings remotely.

Objectives of the Study

The main objective of the study was to design, develop, and implement AquaFlow, an innovative smart irrigation system powered by NodeMCU ESP 8266 with the gate controlled by the servo motor, to improve water resource management by implementing effective measures to mitigate water wastage, ensure continuous monitoring of water level, and provide a user-friendly and ease of access system to the farmers. Specifically, it aims to:

1. Minimize Water Wastage: Reduce water wastage by effectively controlling the water flow using AquaFlow's innovative smart irrigation system.
2. Monitor Irrigation Water Level: Prevent crop damage due to overwatering or underwatering by continuously monitoring water levels in the irrigation system using advanced sensors and automated systems integrated into AquaFlow.
3. Provide Easy User Friendly and Easy Access Application: Design a user-friendly interface for AquaFlow, ensuring that it is straightforward and easy to use for farmers.

Scope and Limitations

The general intent of the study was mainly focused on developing and innovating a smart irrigation system using Arduino technology for Gumain Dam. This system will utilize NodeMCU ESP8266 microcontroller, an open-source electronic platform, to achieve the efficient, effective, and modernized monitoring and controlling irrigation system process to avoid water waste and deaths of crops. The statement above is the scope and Limitations of the project. Utilizing and installing the project to the locale and cost to its range and size required in building the system are the delimitations of the project. The limitations of an Arduino-powered smart irrigation system include the possibility of ultrasonic sensors malfunctioning, which may affect the precise measurement of the water level, and problems with receiving data from other sensors, which could affect system performance. Due to its dependency on a stable power source and Wi-Fi connectivity, the system's operation may be disrupted by power outages and communication range. In addition, extreme weather conditions such as strong winds, heavy rainfall, or flooding can damage sensors along with other irrigation system components like wiring and controllers, resulting in malfunctions and affecting functionality and reliability.

SYSTEM TECHNICAL BACKGROUND

NodeMCU ESP 8266: NodeMCU ESP 8266 is an open-source electronics platform that allows researchers to create interactive electronic devices. It is particularly well-suited for building prototypes and small-scale projects. In the context of a smart irrigation system, NodeMCU ESP 8266 could be used to build the hardware components of the system, including sensors that measure soil moisture, temperature, and other environmental factors.

C++: C++ is a general-purpose programming language that is widely used for developing high-performance applications, including embedded systems and operating systems. In the context of a smart irrigation system, C++ could be used to write the firmware that controls the sensors and other hardware components of the system.

Blynk: Blynk is an ideal choice for implementing smart irrigation systems due to its user-friendly interface, mobile control capabilities, cloud connectivity, device compatibility, data visualization, and development tools. It allows users to easily monitor and control their irrigation settings through a visually appealing dashboard and a mobile app. With cloud connectivity, remote access and data logging are enabled, while integration with various IoT devices facilitates seamless communication between sensors, actuators, and controllers. Blynk's data visualization and analytics features provide valuable insights into irrigation performance, and its prototyping and development tools streamline the creation process of smart irrigation systems.

METHODOLOGY

In this section, the proponents provide an explanation of the study process. The discussion revolves around the tools, methods, and overall approach used, offering readers insight into the reliability and trustworthiness of the findings.

Research Design

A descriptive research design approach used in this study can be a valuable approach to investigate and document the characteristics, features, and functionality of an Arduino-powered smart irrigation system for Gumain Dam. As stated in the article Descriptive Quantitative Research (2021), A descriptive research design is a type of research design that seeks information to characterize a phenomena, situation, or population in a systematic way. The research commenced by conducting an interview with the barangay captain, serving as an essential primary data collection method. This initial engagement with the local authority aimed to gain valuable insights into the community's perspectives, concerns, and existing challenges related to irrigation. The information garnered from this interview laid the foundation for a comprehensive understanding of the community's needs, guiding the subsequent phases of the research. The AquaFlow system was used as a key component in the research study that follows a survey-based correlational-descriptive approach. This research primarily used quantitative methods to collect numerical data. The objective was to investigate and comprehend the efficiency of the AquaFlow Smart Irrigation System within the context of Gumain Dam in Floridablanca, Pampanga. Through the quantitative approach, the study aimed to gather data that allows for the assessment of the system's impact and effectiveness, particularly in the management of water resources in the specified agricultural area.

Data Gathering

For the proponents to be able to get sufficient information for the study, the different tools used in this study went through a reliability and validity test. The results also were based on the judgment of selected respondents. One of the proponents' made tools was the survey questionnaires that were made by the proponents and validated by the proponents Capstone Adviser. The options that were included in the survey questionnaires are Likert scale. The proponents used surveys as part of the data gathering method to guarantee thorough understanding of user opinions and satisfy the goals of the study. These surveys included a single, post-survey. Proponents did not use pre-survey in line with the locale that doesn't have an existing system. On the other side, the post-survey included a user approval testing procedure. The proponents evaluated the prototype system's performance based on user feedback while following the methodology provided in ISO 25010. Proponents were able to determine the efficacy and acceptability of the created prototype through this assessment, guaranteeing that it satisfied the needs and expectations of its intended users.

Respondent of the study

Prior to the study, the respondent group was separated into alpha and beta testers. Five IT specialists worked as alpha testers, extensively evaluating technical issues. Following that, 50 selected farmers who served as beta testers to evaluate the functionality and usefulness of the smart irrigation system. The study's respondents consist of 102 individuals who met specific criteria, demonstrating both their availability and willingness to participate in the post-survey through a purposive sampling technique. According to the Dovetail Editorial Team (2023), Purposive sampling is used when the researcher selects a sample with an objective or target in mind. As a result, the sample is chosen depending on the characteristics or attributes that the researcher wishes to investigate. Participants are selected "on purpose" rather than at random. It is often referred to as judging or selective sampling. The respondents were farmers possessing the requisite experience necessary for a comprehensive evaluation of the smart irrigation technology under investigation. Additionally, experts in the field were included in the respondent group to assess the performance and usability of the smart irrigation system. The evaluation was conducted using the Software Product Quality Model, with a particular focus on adhering to the ISO/IEC 25010 standard.

Table 1. Criteria for Respondents

	Criteria
Alpha Testing	• Participants with expertise in technology, particularly in the field of smart irrigation systems. • Participants who have a basic understanding of the irrigation system's purpose and functionalities. • 3. Participants who express explicit consent to partake and willing to dedicate time for testing the system.
Beta Testing	• Farmers using traditional irrigation methods without advanced technology. • Farmers who own smartphones and are willing to use the dedicated app. • 3. Farmers who express explicit consent to partake and willing to dedicate time for testing the system.
Post-Survey	• Farmers using the water from Gumain Dam for their irrigations. • Farmers using traditional irrigation methods without advanced technology. • Farmers cultivate various crops, such as rice, corn, and vegetables. • Farmers who have access to technology such as smartphones • 5. Farmers who express explicit consent to partake in the survey and are willing to dedicate time for survey participation

Table 2: Respondents of the Study

	Respondents	No. of Respondents
Alpha Testing	IT Experts	[illegible]
Beta Testing	Farmers	50
Post-Survey	Farmers	102

Research Tools and Instruments of the Study

The research instrument is a well-prepared document containing set of questions about the study, which will be designed to capture the responses from respondents for collecting data or information. The proponents designed a questionnaire patterned from the ISO/IEC 25010 Software Quality Model (International Organization for Standardization [ISO], 2005) in evaluating the acceptability of the system and its degree of excellence. It consists of functional suitability, performance efficacy, compatibility, usability, reliability, security, maintainability, and portability. It was subjected to validity by the experts to measure the accuracy and consistency of the items in relation to the study (Bolarinwa, 2015). The primary mode of gathering data was through the floating of questionnaires to respondents via electronic means. The respondents were given questions based on the constructs of the ISO Model. In gathering the above-mentioned data, the proponents undertook the following procedures:

1. The proponents sought permission from the Barangay Chairman of the locale before conducting the study.
2. With the approval of the Dean of the College of Computing Studies, BSIT Chairman, Capstone Adviser and Capstone instructor the distribution of the questionnaires to the respondents at San Pedro, Floridablanca Pampanga.

Statistical Treatment and Data

Weighted Mean

A technique known as weighted mean accounts for the varying levels of significance of the values in a data collection. Prior to the final computation being completed, every integer in a data set will be multiplied by a predetermined weight when calculating the weighted mean (Ganti, 2022).

Formula: $$\frac{\sum x}{N}$$

Where:

$\sum x$ = sum of all data

N = number of respondents

Figure 1: Weighted Mean Formula

Sampling Technique

Purposive Sampling Technique

The main goal of purposive sampling is to concentrate on a subset of participants who fit a specific profile based on credentials and attributes to best address the important research questions. With purposive sampling, which is a non-probability sampling strategy, researchers choose survey participants based only on their subjective assessment. This sampling method is frequently employed in research based on the small sample size of research participants (Elder, 2009). Given that this strategy depends on the proponent's judgment in choosing the study participants for their quantitative data, its proponents advocate using the purposive sampling methodology. Using this sampling approach, the researchers chose the volunteers who best fit these criteria:

1. Farmers who are using the water from Gumain Dam for their irrigation.
2. Farmers using traditional irrigation methods without advanced technology.
3. Farmers who cultivate various crops, such as rice, corn, and vegetables.
4. Farmers who have access to technology such as smartphones

Data Analysis

To examine the collected data, the proponents employed the Likert scale. This scale helps in understanding how respondents perceive and evaluate specific questions. It involves assigning numerical values to the answers, allowing for a more accurate interpretation (Bhandari, 202[illegible]). Statistical methods were used to evaluate user approval based on the post-survey results. This involved calculating out the weighted mean, which gives a summary of the overall perspective or view of the subject. The number of responses was also measured using the standard deviation, which reveals the degree of agreement or disagreement among respondents. These statistical techniques allowed the proponents to gather valuable knowledge from the data, revealing patterns, tendencies, and trends that provided information on the degree of user approval of the study's emphasis.

Table 3: Four-Point Likert Scale

WEIGHT	MEAN	INTERPRETATION
4	3.51 – 4.50	Strongly Agree
3	2.51 – 3.50	Agree
2	1.51 – 2.50	Disagree
1	1.0 – 1.50	Strong Disagree

Ethical Considerations

The proponents exercised the principles of the ethical gathering of data in which Bhandari (2021) stated the following: the data confidentiality of the respondents, data gathering instrument validity, and maintaining the scientific produced data integrity. The data confidentiality of the respondents was focused on maintaining the rights of the respondents for their willingness to answer the questionnaire and protect their anonymity as with the adherence to the Data Privacy Act of 2012 for Republic Act 10173. The validity of the data gathering questionnaire was done through the consultation and validation of the invited information technology professionals before undergoing a post-survey. The maintenance of scientific product data integrity involves the processing of raw data through the use of various statistical methods.

REQUIREMENTS ANALYSIS

The researchers meticulously identified the study's essential requirements during the requirements planning phase of the Rapid Application Development. The researchers conducted extensive research throughout the requirements analysis to ensure that the study meets the user's needs. During this phase, the researchers undertook the task of creating a detailed diagram that visually represents the entire process of the smart irrigation system. To convey the step-by-step operations and intricacies of the system, a flow chart was carefully made. This process flow chart served as a comprehensive blueprint, elucidating each phase and operation within the smart irrigation system. It was designed with a focus on clarity and precision, ensuring that anyone could easily comprehend how the system functioned.

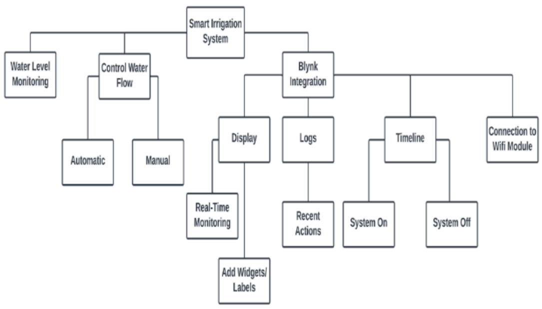

Figure 2: Visual Table of Contents

The researchers meticulously crafted a context diagram to offer readers a high-level perspective of the system under examination. This diagram encapsulates the entire system within a singular entity and adeptly illustrates its interactions with external entities, including users, sensors, and external systems. By meticulously defining the system's boundaries and identifying the external entities it engages with, this context diagram aids readers in comprehending the environmental context in which the system functions. It efficiently communicates what aspects are within the system's purview and what lies beyond, providing clarity and direction for further exploration. The context diagram serves as an entry point, facilitating readers' comprehension of the fundamental components and connections of the system, setting the stage for more comprehensive examinations in subsequent sections of the study.

Throughout the analysis of the system, the researchers employed a Level 1 Data Flow Diagram (DFD) to offer readers an intricate view of the system's internal processes and data flows. This diagram provides an in-depth breakdown of the system's core processes and highlights their interrelationships. By visually depicting the flow of data between processes, data stores, and external entities, it demystifies the routes data takes within the system. Moreover, the Level 1 DFD introduces the concept of subprocesses, enabling readers to gain insight into how overarching processes are deconstructed into smaller, manageable elements. This level of detail is imperative for a comprehensive grasp of the system's internal structure and the pathways for control command flow. In essence, the Level 1 DFD divulges the nuanced mechanisms governing the system, unveiling the data processing flow and the intricacies of process coordination. Alongside accompanying explanations, this diagram equips readers with a profound comprehension of the system's inner workings, serving as an invaluable asset in the study for elucidating intricate system dynamics.

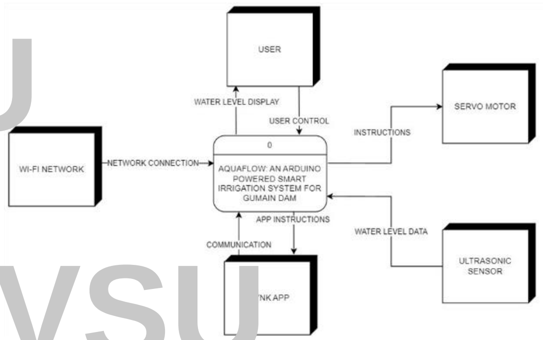

Figure 3: Data Flow Diagram Level 0

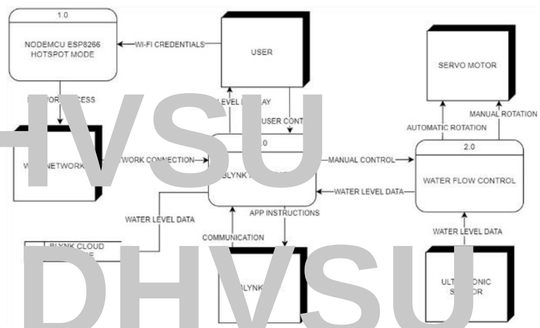

Figure 4: Data Flow Diagram Level 1

System Development Methodology

In developing the Smart Irrigation System, the proponents have devised a System Development Methodology rooted in Rapid Application Development (RAD). This innovative approach unfolds in four key phases: Requirements Planning, User Design, Construction, and Cutover. Each phase was carefully designed to foster rapid iterations, close collaboration with stakeholders, and user-centric design, ensuring the resulting system aligns seamlessly with the dynamic needs of modern agriculture.

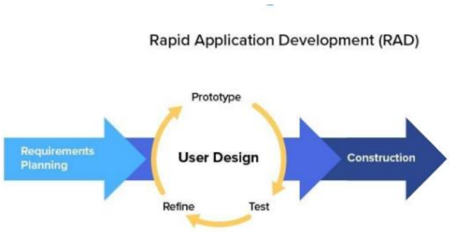

Figure 5: Rapid Application Development Figure

Rapid Application Development, or RAD, is a flexible approach to software development that places less of a focus on detailed design and more on experimentation and quick feedback. In general, the RAD approach places more emphasis on prototyping and development than it does on planning.

Requirements Planning

The initial step of the RAD-based technique for the Smart Irrigation System is assigned to Requirements Planning. During this stage, the proponents collaborated closely with stakeholders to develop and collect detailed requirements. The emphasis here is on rapid inquiry and comprehension. This phase relied heavily on rapid iterations and feedback collecting allowing the team to quickly revise and fulfill the system's needs. The goal was to ensure that the system's functionality properly aligns with the needs and expectations of smart irrigation users and other stakeholders.

System Development Framework

The proponents used Rapid Application Development for developing the prototype system. According to Dogiparthi (2019), Rapid Application Development (RAD) refers to a method for developing software that does not invest a lot of resources or time on planning and instead uses a prototype process to introduce the product. In essence, RAD prioritizes the production of functioning prototypes as a critical component of the process. RAD emphasizes the rapid creation of these prototypes rather than investing significant time and resources to preliminary development preparation. These prototypes function as physical representations of the envisioned system, allowing stakeholders to engage with and provide input on a working model.

Work Plan

The smart irrigation system. It helped the proponents to develop the system where it needs to meet the requirement functions that are added to the system. The system allows the user to view the water level of the main irrigation and its sub-irrigation. By using the ultrasonic sensor, it will measure the water level of the irrigations then send the data through NodeMCU ESP8266 Wi-Fi Module to the Blynk App to be viewed by the user. With this water level data, the servo motors will rotate based on how high or low the water level data is received from the ultrasonic sensors. Also, the user can choose if they want manual control of the servo motors for controlling the water flow in the irrigation.

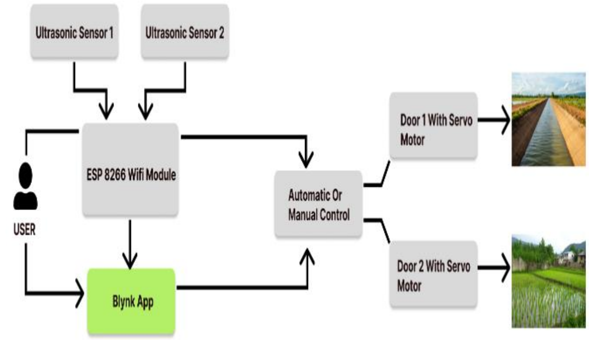

Figure 6: Work Plan

Software Development Tools

The Smart Irrigation System is supported by C++ as the programming language due to its efficient memory management, low-level capabilities, embedded systems, IoT communication, complex algorithms, real-time data analysis, and secure IoT communication protocols.

Blynk enables smart irrigation systems by providing an easy-to-use interface to operate irrigation schedules and data monitoring. It provides real-time monitoring, remote control, flexible scheduling, push notifications, data logging, IoT device integration, customization, and rapid prototyping. Users can manage irrigation schedules, control watering, and observe sensor data to assist with smart irrigation decisions. Blynk also supports a number of communication protocols, allowing it to be integrated with IoT devices. The visual interface of the app and pre-built widgets speed up prototyping, making it easier for users to interact with and control the system.

REQUIREMENTS DOCUMENTATION

Enhancing water usage, improving crop yields, and contributing to sustainable agriculture are the goals of developing an innovative and effective irrigation system to help farmers. The proponents conducted a study and held multiple meetings to determine the system's approach and how it would turn out. To discuss and plan their actions, the meetings were conducted in person. The team discussed many aspects of the system during these meetings, particularly its design, functionality, and features. The proponents conducted a study to learn more about smart irrigation systems and traditional irrigation. The proponents discovered Gumain Dam for construction by examining existing methods and technologies, and they determined how the AquaFlow system could provide additional features to improve the efficiency of irrigation. Prior to the installation of the system, the necessary information was gathered. The proponents implement the system with careful planning and monitoring to guarantee that it meets the study's objectives by closely monitoring each stage of the development process. This approach helps in maintaining focus, tracking progress, and making the necessary adjustments to guarantee that the final system meets the specified objectives.

DESIGN OF SOFTWARE SYSTEM

The researchers have designed a smart irrigation system as a component of the system, with the primary objective of optimizing water usage in agriculture through real-time monitoring and control. This section presents an overview of the key design elements and considerations that have been integrated into the development of this system.

System Architecture:
The core of the smart irrigation system was built upon a robust architecture that seamlessly integrates hardware and software components. The researchers have meticulously selected and incorporated the following elements:

1. **Water Level Monitoring:** Ultrasonic sensors have been employed to accurately measure the water level in the irrigation reservoir. Real-time data from these sensors empowers the researchers to make data-driven decisions regarding irrigation water flow control.
2. **Water Flow Control:** Servo motors, controllable remotely and also automatically rotate based on the water level, are fundamental in regulating the flow of water. This feature ensures precise and efficient distribution of water to the crops, as deemed necessary by the researchers.
3. **Blynk App Integration:** The heart of the system lies in its integration with the Blynk app. This user-friendly mobile application provides a convenient interface for the researchers to monitor water levels and remotely control water flow all through their smartphones.

PRODUCT AND PROCESS

The Smart Irrigation System is an innovative solution designed to optimize water usage in agricultural or gardening applications. It incorporates an ultrasonic sensor and ESP8266 Wi-Fi module and Blynk software for monitoring. Also, servo motors, and an ESP8266 Wi-Fi module for water flow control. This system aims to automate the irrigation process by accurately measuring the water level within the crop field and efficiently distributing water based on the specific crop's water requirements. By leveraging IoT technology, users can remotely monitor the irrigation system through the Blynk Software. The Smart Irrigation System is designed for farmers, agriculturalists, and gardeners who seek an efficient and automated irrigation solution. It is suitable for small to large-scale crop fields or gardens, where precise water management is essential for optimal crop growth and resource conservation.

The expected results of implementing the Smart Irrigation System are numerous. Firstly, it maximizes water efficiency by delivering water precisely, preventing overwatering or underwatering and minimizing water waste. This contributes to resource conservation and promotes sustainable agriculture practices. Secondly, the system saves valuable time and effort for users by automating the irrigation process. By remotely monitoring the water level and controlling the water flow through the system by using the Blynk application, users can make informed decisions and adjustments promptly, without the need for manual intervention. Next is crop yield optimization, through the Smart Irrigation System where it provides the right amount of water for every crop and it helps to optimize crop yield. It ensures that crops receive adequate moisture for healthy growth, leading to improved quality and quantity of the harvest. The system also promotes sustainable agriculture by conserving water resources. It minimizes water waste by precisely irrigating based on actual crop needs, reducing environmental impact.

To achieve these results, the implementation process involves strategic steps. This includes proper placement of the ultrasonic sensor within the crop field. Installing the ultrasonic sensor at an appropriate height within the crop field to accurately measure the water level. Secure it firmly, ensuring it is not obstructed by plants or other objects. Securing hardware setup, connecting the components, and programming the Arduino to read data from the sensor and control the servo motor based on water level thresholds. Configuration of the ESP8266 Wi-Fi module ensures seamless connectivity, enabling communication and facilitates access via the user-friendly Blynk application. Thorough testing and calibration guarantee accurate sensor readings, reliable communication, and appropriate water flow control. Regular maintenance and software updates are essential for optimal performance. By following this process methodology, users can achieve the expected results of water efficiency, time savings, crop yield optimization, resource conservation, and remote monitoring and control, thus enhancing their irrigation practices and crop production.

DEVELOPMENT AND TESTING

In the development stage the developers gathered all the required components for the smart irrigation system prototype. The developers carefully selected each component, ensuring compatibility and functionality aligned with their envisioned system. The core of the developer's setup was the ESP8266 Wi-Fi module, which provided the microcontroller capabilities necessary for controlling the smart irrigation system while also enabling wireless connectivity for remote access and control. A servo motor was chosen to control the water flow. To measure the distance to the water level, an ultrasonic module was included. The breadboard served as a flexible platform for circuit prototyping, while jumper wires facilitated the necessary connections. Resistors were procured to handle current control and voltage regulation. Then Arduino IDE was installed and its necessary libraries for the coding of ESP8266 Wi-Fi module. Finally, the Blynk platform was used for the graphical interface and for real time monitoring.

In the testing phase, it went through alpha and beta testing to ensure its functionality, performance, and user satisfaction. During the alpha testing phase, the system was tested in a controlled environment by the development team. The system's components, circuits, and software have been examined to identify any bugs, inconsistencies, or design flaws. Feedback from the alpha testing helped the developers to refine and improve the prototype.

Following the alpha testing, the system progressed into the beta testing phase, during which a selected group of farmers had the opportunity to evaluate the prototype. These farmers provided valuable insights into the prototype's usability, effectiveness, and reliability. They reported any encountered issues, such as connectivity problems, inaccurate sensor readings, and more. The developers closely monitored the beta testing, collecting feedback and addressing the identified issues through iterative updates and refinements to enhance the prototype's performance and functionality.

IMPLEMENTATION PLAN

The deployment, installation, and conversion of the irrigation system into a functioning condition are all included in the implementation plan. Tasks including system deployment, setup, user training, testing, change management, and the go-live procedures are all included in this extensive strategy. Hardware, software, client, and materials are among the resources that are needed. The interaction with current systems, user access, and backup processes are all covered by the implementation criteria. The depth of the plan is highlighted by a timetable with checkpoints, risk management plans, funding allocation, assessment techniques, and a dedication to a smooth transition. Within the scope area, the objective is to guarantee and improve user experience.

Table 4: Implementation Plan

Strategy	Activities	Person Involved	Duration
Development of a risk management policy	Review the policy recommended by the administrator	Proponents/ Administrator	1 Day
Hardware installation	Installation of Arduino	Proponents	1 Day
Software installation	Installation of Blynk app	Proponents	1 Hour
Assemble of the Prototype	Test the functionality and accuracy	Proponents	1 Day
User training	Provide training on its operation and maintenance	Proponents/ Administrator	3 Days
Feedback	Gather feedback from users and stakeholders	Proponents	1 Day

IMPLEMENTATION RESULT

The implementation plan activities were successfully executed within the allocated timeframes. The result is a fully functional irrigation system comprising installed hardware and software components. Users have been trained for effective operation and maintenance. Feedback collection ensures ongoing improvements and user satisfaction. The irrigation system is now operational, meeting the objective of the implementation plan.

Table 5: Implementation Result

Activities	Person Involved	Duration	Status
Review the policy recommended by the administrator	Proponents/ Administrator	1 Day	Completed
Installation of Arduino	Proponents	1 Day	Completed
Installation of Blynk app	Proponents	1 Hour	Completed
Test the functionality and accuracy	Proponents	1 Day	Completed
Provide training on its operation and maintenance	Proponents/ Administrator	3 Days	Completed
Gather feedback from users and stakeholders	Proponents	1 Day	Completed

Table 6. Hardware and Software Requirements for Mobile Client

Item	Minimum Requirements	Recommended
Processor Speed	1.5Ghz	2.5 Ghz
Processor Type	Snapdragon 636 1800 Mhz Nexus One (1Ghz) Nokia N900 (600 Mhz) Apple 4	Snapdragon 888 2840 Mhz Apple 12
Memory	2GB RAM	4GB RAM or Higher
Operating System	Android 4.0 IOS 4	Android 11 IOS 11 or Higher
Storage	16 GB ROM	64 GB ROM

RESULT AND DISCUSSION

This section will show the summary of findings that answers the objectives of the study stated by the proponents. Along with the summary of findings are the conclusions and the recommendations that can used for future the research.

Objective 1 - **Minimize Water Wastage:** The impressive Performance Efficiency rating of 3.61 signifies that the prototype system is not only preventing water wastage but is also actively contributing to higher levels of water conservation and efficiency. This outcome is particularly significant as it has the potential to lead to substantial cost savings for farmers and has positive environmental implications. By optimizing water usage, the system aligns with sustainable farming practices, reducing the strain on water resources. The system utilizes a servo motor to control water flow, responding to the data transmitted by the ultrasonic sensor.

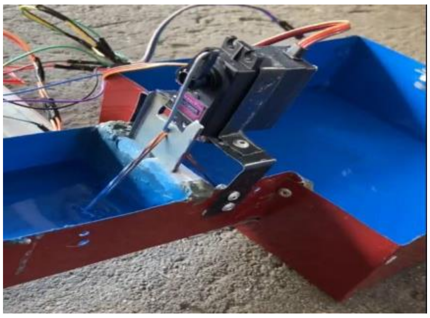

Figure 7: Ultrasonic Sensor

Objective 2 - **Monitoring Water Level**: The prototype system's excellent performance in monitoring water level, with a Usability rating of 3.48, indicates that it is not only technologically sound but also user-friendly. This means that farmers can easily access and make use of the system, ensuring efficient water level management. Efficient water level management, in turn, translates to healthier crops and better yields, ultimately benefiting the agricultural community. By using an ultrasonic sensor, the system measures the water level and sends the data to the Blynk application, enabling real-time monitoring of water levels.

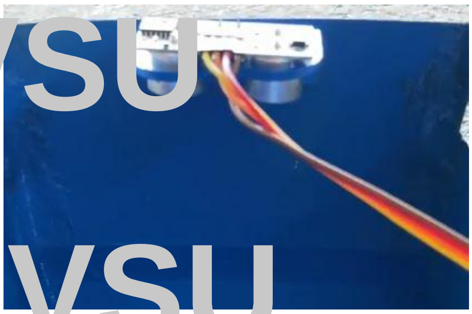

Figure 8: Servo Motor

Objective 3 - **User friendly and Easy Access**: The high Functional Suitability rating of 3.48 highlights the system's user-friendliness and effectiveness in managing water flow. It features intuitive controls for water flow management, real-time monitoring of irrigation levels, and easy navigation. The clear and visually appealing design contributes to the overall effectiveness of the system, ensuring a seamless experience for farmers. The AquaFlow User Interface (UI) is designed with a focus on user-friendliness and utilizes the Blynk application as a tool for creating the UI.

Figure 9: AquaFlow User Interface

In summary, the prototype water management system represents a significant advancement in agricultural practices. Its ability to optimize water usage, monitor water level, and ensure fairness in water distribution holds the promise of improving crop yields, conserving precious water resources, reducing operational costs for farmers, and promoting sustainable agriculture. Moving forward, it is essential to consider the wider adoption of such systems to support a more environmentally conscious and economically sustainable agricultural sector. Further research and implementation are warranted to realize their potential benefits fully.

Post-Survey Results

Table 7. Post-Survey Results

ISO CHARACTERISTICS	Mean	Interpretation
Functional Suitability	3.64	Agree
Performance Efficiency	3.61	Strongly Agree
Reliability	3.50	Agree
Usability	[illegible]	Agree
Maintainability	3.49	Agree
Security	3.48	Agree
Compatibility	3.45	Agree
Portability	3.42	Agree
Acceptability	3.56	Strongly Agree
TOTAL MEAN	**3.51**	**Strongly Agree**

Functional suitability received a high mean score of 3.64 in the post-survey given that the system is user-friendly and rarely produces errors. However, portability received a low rating of 3.42 for the reason that it was challenging for end users to transport the system. The post-survey's overall mean of 3.51 indicated agreement among respondents, suggesting that the end user considered the system was functioning well.

Alpha and Beta Testing Survey Results

The study began by categorizing respondents into two groups: Alpha and Beta testers. Initially, five IT specialists served as alpha testers, focusing on thorough evaluations of technical aspects.

Table 8. Alpha and Beta Testing Survey Results

ISO CHARACTERISTICS	Alpha Testing Mean	Beta Testing Mean
Functional Suitability	3.7	3.4
Performance Efficiency	3.68	3.4
Reliability	3.64	3.33
Usability	3.6	3.27
Maintainability	3.61	3.4
Compatibility	3.71	3.6
Portability	3.72	3.2
Acceptability	3.8	3.73
TOTAL MEAN	**3.68**	**3.42**

In the beta test, acceptability achieved the highest mean score of 3.78, as selected testers found the system's features make the water control and monitoring convenient. On the contrary, usability recorded the lowest mean score of 3.60 due to unexpected malfunctions and errors during testing. The overall mean of the beta test was 3.68, signifying a high level of agreement among testers, with the majority expressing strong agreement, indicating that the system was widely regarded as excellent. Acceptability received the highest mean score of 3.8 in the alpha test, as testers found the system to be user-friendly. Due to minor bugs in the system's controls, portability received the lowest mean score of 3.2. The overall mean of the alpha test was 3.42, with the result being Agree, indicating that the testers agreed that the system is generally good.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

The main objective of the study was to develop and implement AquaFlow, a smart irrigation system using NodeMCU ESP 8266 and a servo motor-controlled gate, aiming to enhance water resource management at Gumain Dam. This involves minimizing water wastage, continuously monitoring water level, and a user-friendly interface for the users. The AquaFlow capstone project is dedicated to creating a smart irrigation system utilizing Arduino technology for Gumain Dam in Floridablanca, Pampanga. Its primary goal is to reduce water wastage and improve irrigation practices in the associated agricultural fields. Employing a descriptive quantitative research design, the project addressed issues concerning water waste and crop damage prevalent in traditional irrigation practices. During the Rapid Application Development (RAD) phase, crucial requirements were thoroughly identified to ensure alignment with user needs. A comprehensive suite of visual aids, including detailed diagrams such as flow charts, context diagrams, and a Level 1 Data Flow Diagram, was created to elucidate the processes and functions of the smart irrigation system. In evaluating its effectiveness at Gumain Dam, survey-based correlational-descriptive quantitative research was conducted using the system. The proponents adopted RAD methodology for developing the prototype, integrating key components like the NodeMCU ESP8266 microcontroller, an ultrasonic sensor, and a servo motor for water flow control. This integration was achieved using the Arduino IDE and the Blynk Application. Post-development, the system underwent alpha and beta testing, and assessment ensued following the ISO 25010 standard. The study concludes that the prototype water management system exhibits substantial potential to transform water utilization practices within agricultural irrigation.

Conclusion

Based on the study's findings, local farmers have been able to optimize water usage and improve the efficiency of their irrigation procedures at Gumain Dam, Floridablanca, Pampanga, as a result of the introduction of the AquaFlow Smart Irrigation System. The system's automated regulation of water flow by the servo motor and real-time water level monitoring displays a significant positive impact on both farm productivity and water conservation. Through the use of modern technology, the Smart Irrigation System helps to promote sustainable farming methods while simultaneously addressing the problem of water irrigation. Combining the quantitative data gathered from surveys with the positive feedback from farmers highlights how effective the approach is at encouraging water efficiency and cutting down on waste. The primary goals of the AquaFlow Smart Irrigation System have been successfully met. AquaFlow has proven to be highly efficient at controlling water flow by placing a high priority on minimizing water waste. This has made a substantial contribution to sustainable agricultural methods. By using advanced sensors and automated systems, to monitor the irrigation water levels, guaranteeing crops get the right amount of water, and minimizing potential harm has been accomplished. Furthermore, by enabling easy access and navigation, the system's dedication to a user-friendly interface has helped farmers using the system. Future research and development can look into future improvements, integration with other sensors, and user-friendly interfaces to further ease its application and accessibility. Therefore, AquaFlow represents not just a technological advance but also a full range of tools that assist farmers in effective and sustainable irrigation management techniques, promoting a more resilient and fruitful agricultural environment.

Recommendations

After the research findings and conclusions, the following recommendations can serve as valuable guidance for future researchers aiming to create systems with similar services and capabilities.

1. Microcontrollers, sensors, and other components can all be improved to enhance the performance of the system for better accuracy of data and performance of the system.
2. Scheduling features can be integrated to increase the efficiency of the system.
3. Other components such as soil moisture can be integrated for more additional monitoring readings.
4. Integration with Weather Forecasting API to anticipate weather conditions and to adjust irrigation plans.
5. Include an external power source, such as hydroelectric power or solar for sustainability and making the system more energy-efficient.
6. Enhance system UI/UX through user-driven design improvements for better accessibility and user-friendliness.

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