# Smart water tank system using WIFI-based microcontroller unit

DOI: 10.46932/sfjdv3n2-086

Received in: February 15th, 2022
Accepted in: March 1st, 2022

**Dachel P. Raagas**
MIT Student
Institution: Leyte Normal University
Address: Paterno St., Tacloban City 6500, Leyte, Philippines
E-mail: dachelraagas@evc.pshs.edu.ph

**Donn Emile Kylee M. Melgazo**
Engr
MIT Student
Institution: Leyte Normal University
Address: Paterno St., Tacloban City 6500, Leyte, Philippines
E-mail: donnkyleemelgazo@gmail.com

**Dave Christian S. Ergina**
MSIT Student
Institution: Leyte Normal University
Address: Paterno St., Tacloban City 6500, Leyte, Philippines
Email: dave.sudario.ergina@gmail.com

**Rommel L. Verecio**
DM-HRM, JD
MIT/MSIT Faculty
Institution: Leyte Normal University
Address: Paterno St., Tacloban City 6500, Leyte, Philippines
E-mail: rlverecio@lnu.edu.ph

## ABSTRACT
The water system infrastructure in the Philippines can be classified into: Stand-alone water points, piped water with a communal water point, and piped water supply with a private water point. At certain times of the year, households face the dilemma of an overflowing tank when the water pressure from the local water district is high. Conversely, the water tank goes empty during the dry season when the water supply from the local service provider is low. It is during the dry season that households stay up late at night or until early morning to watch and/or fill their water reservoir. When the water pump is turned on and left unattended, water overflows. Filling in the water tank manually results in water waste. Thus, there is a need for a solution to automate the turning off of the water tank when the full level is reached. This study presents a design and a prototype of a WiFi-based device called Smart Water Tank System (SWaTS). This system includes a hardware interface module. Its functional features are programmed using the Arduino IDE which provides a library of functions supporting a wide array of sensors and actuators. The functional test on SWaTS proved that it can provide a solution by real time water level monitoring. The water pump will automatically start when the water hits a critical low level and will automatically turn off when it reaches a near full level. With this, the tank will neither be empty nor overflow.

**Keywords**: microcontroller, smart system, internet of things, water tank automation, sensors.

## 1 INTRODUCTION

Water is an essential life support similar to air. Water is a valuable resource for a sustainable life (Sayyed & Aziz, 2021, #240).

The Philippines is endowed with rich natural resources, including water, which are essential for the country's economic development. Water resources of the Philippines include inland freshwater (rivers, lakes, and groundwater), and marine (bay, coastal, and oceanic waters). Overall, there is sufficient water but not enough in highly populated areas, especially during the dry season. The Government's monitoring data indicates over a third or 36 percent of the country's river systems are classified as sources of public water supply. (The World Bank Group, 2003, 9)

Water supply is the process of providing water in a systematic way through installed pumps and pipelines (Definitions.net, n.d.). Before water is provided to a specific area, it undergoes a process called sanitation to ensure that the quality of water received is safe for human consumption. (HiSoUR.com, n.d.)

There are three levels used to designate water systems infrastructure in the Philippines (World Bank, 2007,5). Level 1 - Stand-alone water points (e.g. hand pumps, shallow wells, rainwater collectors) serving an average of 15 households within a 250-meter distance. Level 2 - Piped water with a communal water point (e.g. borewell, spring system) serving an average of 4–6 households within a 25-meter distance. Level 3 - Piped water supply with a private water point (e.g. house connection) based on daily water demand of more than 100 liters per person. Many service providers like Local Government Units, local water districts, large scale Private Operators, and small-scale Independent Providers ushered the access to improved water sources.

The Philippine's Department of Environment and Natural Resources and its River Basin Control Office reported that 70% of the country's available water of 160 billion cubic meters per year is wasted or lost. Water unused or lost refers to the non-revenue water of water districts due to leaking pipes, as well as those that are not directly caught by irrigation areas. Vicente Tuddao, executive director of the DENR's River Basin Control Office (RBCO) warned that by year 2025, 1.8 billion people would be living in countries or regions with absolute water scarcity, and two-thirds of the world's population could be living under water stressed conditions. (Villanueva, 2012). Hence, efficient management of the water used at homes is very much necessary (Nishmitha et al., 2021, 1).

Many households in the area make use of supplementary water tanks to store water that is collected from rain water, water pumped from underground wells, or water pumped from local water district distribution facilities. At certain times of the year households face the dilemma of tank overflows when the water pressure from the local water district is high. Conversely, the water tank goes empty during the dry season when the water supply from the local service provider is low. It is during the dry season that households stay up until late at night to watch and/or fill their water reservoir. Manual refilling of water tanks results in water being wasted. When the water pump is turned on and left unattended, the water overflows.

Consumer lines also contribute to wastage of water due to leaking pipes, improper/excessive collection and use of water, not to mention water overflows in tanks. Electric water pumps installed on supplementary water tanks do not totally provide an efficient means of water management at home. It even adds up the household cost. Hence, there is a need to modify the traditional water collection in homes into a worry-free and zero waste infrastructure.

Internet of Things (IoT) is a term used for all technologies that enable the connection of a device to the Internet. IoT systems depend on the collection of data used for monitoring, controlling and transferring information to other devices via the internet. The collected data allows specific actions to be automatically activated whenever certain situations arise. Instead of manually going up to the device and taking action, those actions can be taken at the press of a button. (iot-now.com, 2020)

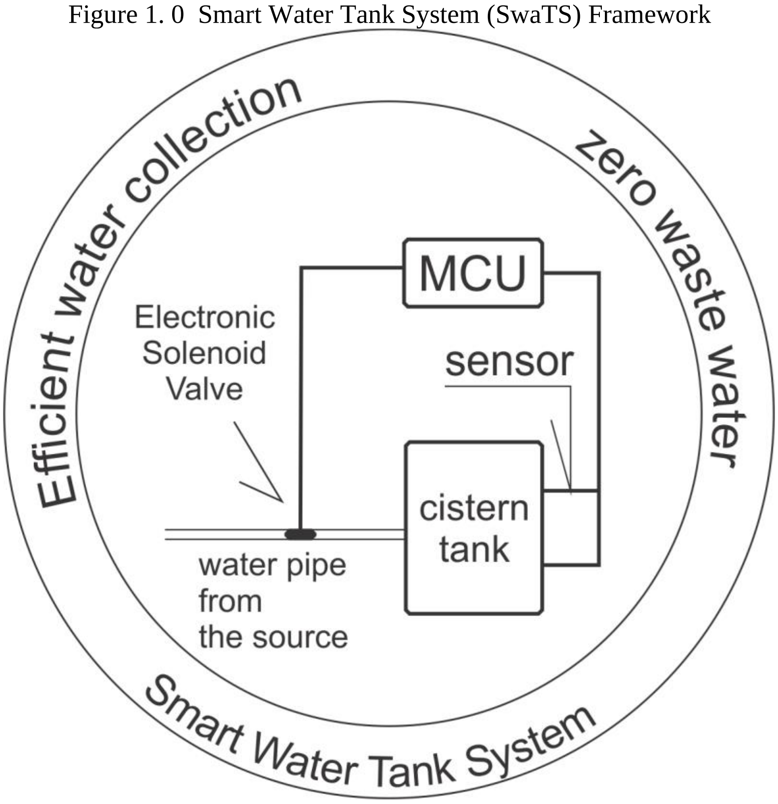
WiFi technology is a network infrastructure connecting a web server which manages, controls, and monitors users' homes locally or remotely. Typically, a hardware interface module provides the appropriate interface to sensors and actuators of home automation systems and with one server able to manage many hardware interfaces like power management components, and security components within the WiFi network coverage. (ElShafee & Hamed, 2007, 2177)

Along with many other IoT supporting devices is the ESP8266 or ESP32. ESP32 as a low-cost, low-power system on a chip (SoC) series with Wi-Fi & dual-mode Bluetooth capabilities. An earlier version of ESP32 is ESP8266 (esp32.net, n.d.). Hamsa Iqbal (2019) demonstrated some techniques of connecting some home appliances to the relay module and controlling it through ESP32 Microcontroller. He constructed a firebase real-time database and connected it from the android app. The android app sends the data to the cloud which then sends it to the microcontroller to switch the electrical appliance on or off.

## 2 FRAMEWORK OF THE STUDY

The researchers are motivated to build a water tank infrastructure (see Figure 1.0) that supports water level monitoring and aimed to fix the problems of having an empty water tank and overflowing water. Specifically, it would help in eliminating the need for a person to turn the water tank off when it's full, and turn on when it's empty. Emerging technologies like smart homes, Arduino, and Internet of things (IoT) technology have changed the practice of water collection. Applying the idea of IoT, using a Microcontroller Unit (MCU) that can be programmed through Android Integrated Development Environment (IDE); the smart water tank is designed to stop collecting water if the water pressure is low or close the Solenoid valve to stop water collection when water in the tank reaches the FULL level. As an additional feature the smart tank via WiFi connection and the internet can also send notification to the homeowner about the water level in the tank. The smart water tank can provide a solution by real time water level monitoring. The communication between the sensors and the microcontroller unit will automatically OPEN the valve when the water in the tank hits a critical low level and will automatically CLOSE when it reaches a near full level. With this, the tank will neither be empty nor overflow. Thus, saving water and electricity.

Figure 1. 0 Smart Water Tank System (SwaTS) Framework




## 3 OBJECTIVES OF THE STUDY

This research aims to develop an innovative solution using the microcontroller, sensors, WIFI technology and Arduino programming. It will give information as to how technology can help reduce wasted water.

The study will seek to answer the following questions:

- How can empty water tanks be filled in without the need to physically access the tank?
- How can tank water waste be reduced?
- How can preventing water tank overflow help the environment?

## 4 METHODOLOGY

### A. Research Design

This section justifies the specific procedures or techniques used to develop, and test the product of the study.

The work will follow steps in developmental research. Developmental research is the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet criteria of internal consistency and effectiveness. The most common types of developmental research involve situations in which the product-development process is analyzed and described, and the final product is evaluated. (Richey & Nelson, 2001, page 1)

The product of this study is a Smart Water Tank System (SWaTS) which will be designed to reduce if not eliminate the amount of wasted water, reduce cost on water and electricity, and eventually contribute to conservation of the environment's valuable resource which is water.

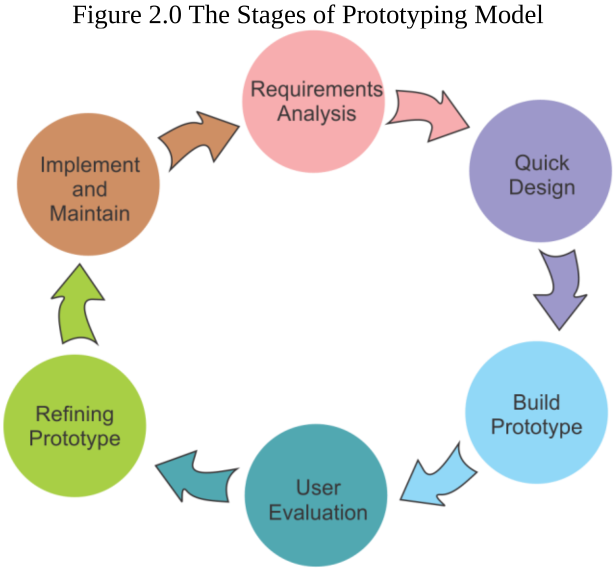
The work is a partial fulfillment of the requirements in the Master in Information Technology (MIT) and in Master of Science in Information Technology (MSIT) graduate programs of the Leyte Normal University, Tacloban City, Philippines.

### B. Research Procedure

This section discusses prototyping methods to build and test the Smart Water Tank System (SWaTs). In building the solution, the proponents follow the System Development Life Cycle and the prototyping approach (see Figure 2.0) applying the ideas of emerging technologies like Internet of Things (IoT) and microcontroller programming. The proposed solution would benefit homeowners, industry and organization.

Prototyping Model is a development model in which a prototype is built, tested, and reworked until an acceptable prototype is achieved. It also creates a base to produce the final system or software. It works best in scenarios where the project's requirements are not known in detail. It is an iterative, trial and error method which takes place between developer and client. (Guru99 Tech Pvt Ltd, 2019). Figure (2) shows the stages of prototyping method.

Figure 2.0 The Stages of Prototyping Model




1. **Requirements Gathering and Analysis.** A prototyping model starts with requirement analysis. In this phase, the requirements of the system are defined in detail. During the process, the users of the system are interviewed to know what is their expectation from the system. (Guru99 Tech Pvt Ltd, 2019).

In defining the requirements to build the proposed solution, the proponents consulted experts in electronics and communications to determine appropriate components to include in the design of the product.

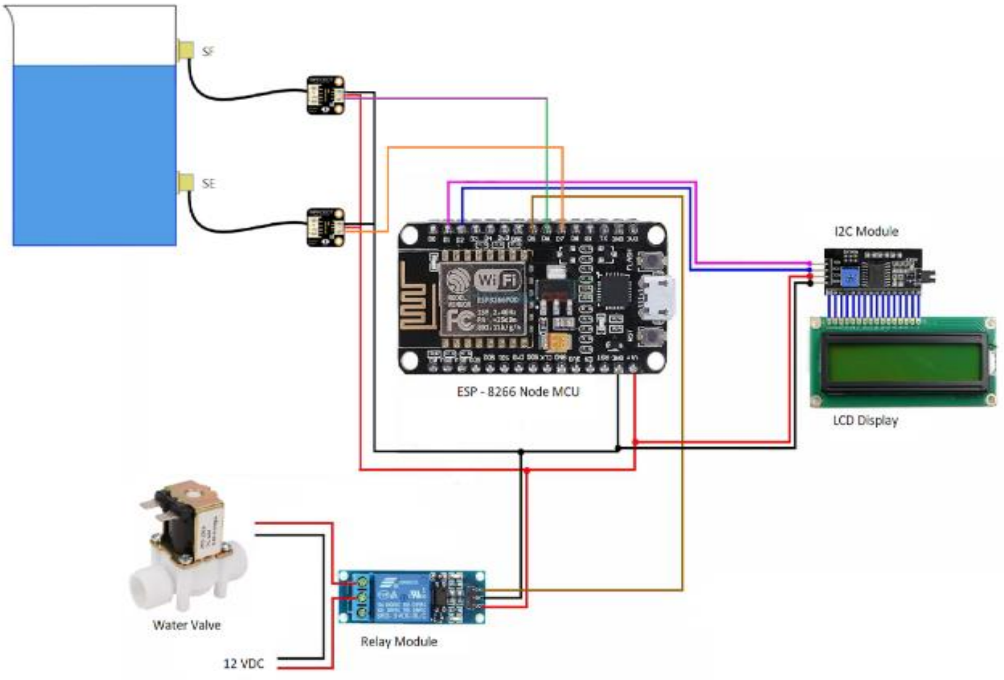
The hardware specifications required to build the smart water tank system, includes the following:

- **Display interface (LCD) for tank water-level monitoring.**
- **Water flow control.** An all-brass electric solenoid pressure regulating valve with 12V DC Supply and can handle 0.02-0.8mpa water pressure. This electric solenoid valve is all brass casting structure, precise and reliable, has the characteristic of wear-resistant, anti-corrosion and high temperature resistance. (hweitugroup.com, 2021)
- **Sensor.** Non-contact liquid level sensor, compatible with 5-24V power supply. 13mm or more induction distance. (DFRobot.com, n.d.)
- **Microcontroller Unit (MCU).** SWaTS hardware aspect consists of two (2) different Printed Circuit Board (PCB): the New Nodemcu Baseboard PCB , and the NodeMcu V3 Lua WIFI Development Board ESP8266 Serial Wifi Module**.** A development board with built-in WIFI/Bluetooth and Deep Sleep Operating features suitable for IoT Projects. Powered by Micro USB jack or an external Power Supply (7-12V).

2. **Quick design.** The proponents brainstormed on a design upon which to build SWaTS' prototype. The initial conceptual design of the SWaTS prototype was making use of an Ultrasonic

sensor. After discussing the pros and cons with the functional life of the ultrasonic sensor being installed inside the tank; that it will be exposed to moist and water vapor; the researchers decided to modify the design. Figure 3.0 shows the block diagram for SwaTS

Figure 3.0 Smart Water Tank System Block Diagram




The modified design made use of the Node MCU that collects information from the contactless water sensor (Sensor Full - SF and Sensor Empty – SE). Then, the Node MCU will run algorithms and send data to the LCD I2C. Once the LCD I2C displays the notification, the Node MCU will give a signal to the relay for it to turn off or on. When the relay is on, the water valve allows water to pass. Otherwise, the water valve will not allow the water to pass.

## 2.1 User and Characteristics

The proposed SWaTS would be designed as a tool for ordinary users. An ordinary user is defined in this study as someone possessing general knowledge and skills in the use of computers and its operating system like Windows, general knowledge in the use of the internet, particularly the use of web browsers like Google Chrome, Microsoft Edge, and the like.

3. Build a Prototype. On this stage, the SWaTS diagram is turned into a concrete build including all the necessary pipe fittings (see figure 4). The Solenoid Valve is attached to the inlet pipe and is then connected to the ESP8266 MCU to prepare for programming. The LED Display and the non-contact water level sensor detection are connected to the ESP8266 MCU board to prepare for programming.

Programming SWaTS includes interfacing the ESP8266 Microcontroller Unit (MCU) to the water tank, then programmed for communication and control. The instruction set is written to the firmware.

Figure 4. Snapshot of the Smart Water Tank System (SWaTS)

SWaTS requires the use of two softwares: The Microcontroller (Arduino IDE) firmware and the Telegram app.

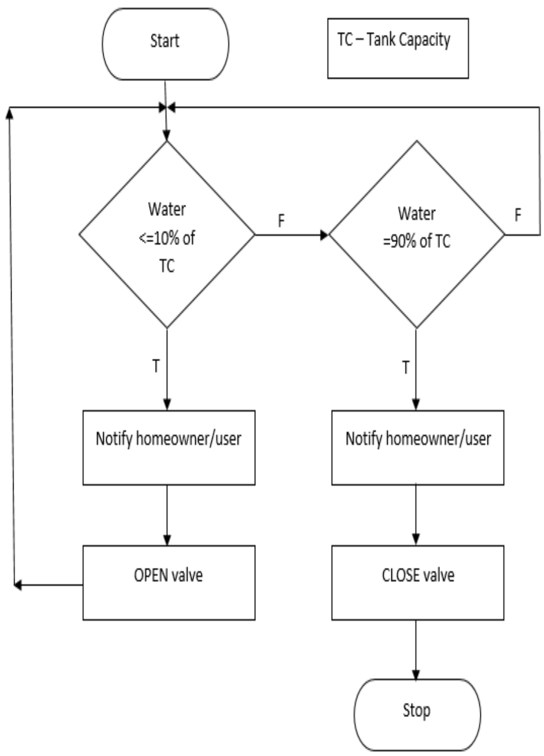
Telegram Messenger is a cloud-based instant messaging and voice over IP service. You can easily install it in your smartphone (Android and iPhone) or computer (PC, Mac and Linux). It is free and without any ads. Telegram allows you to create bots that you can interact with. The ESP32/ESP8266 will interact with the Telegram bot to receive and handle the messages, and send responses (Santos & Santos, 2013-2021).

*Bots* are third-party applications that run inside Telegram. Users can interact with bots by sending them messages, commands and inline requests. You control your bots using HTTPS requests to Telegram Bot API“ (Telegram FZ-LLC, n.d.).

The Software - Arduino Integrated Development Environment (IDE) - is an open-source cross platform development environment built using the C language. It allows you to write programs and upload them to your board. (Arduino, 2021)

Arduino is responsible for collecting events from connected sensors, then applying actions to actuators like the Solenoid Valve. Figure (5) shows the system flow of the proposed SwaTS.

Figure 5. System Flowchart for the Smart Water Tank System (SWaTS)




Below are the functions and the libraries used for SWaTS operational design:

**#include <LiquiCrystal_I2C.h>** This line includes the LCD I2C Library.th

**#include <ESP8266WiFi.h>** This line includes the ESP8266WiFi library. This library provides ESP8266 specific Wi-Fi routines that are called to connect to the network.

**#include <WiFiClientSecure.h>** This line includes the WiFiClientSecure library. Wificlientsecure will send an SSL Fingerprint to web pages has an SSL protection. It will verify your that your connection is secure depending if you have a fingerprint of not.

**#include <UniversalTelegramBot.h>** This library is used to create your own Telegram Bot using ESP8266 on Arduino IDE.

**#include <ArduinoJson.h>** A simple and efficient JSON library for embedded C++. Arduino JSON supports serialization, deserialization, MessagePack, fixed allocation, zero-copy, streams, filtering, and more.

**#define BOT_TOKEN**

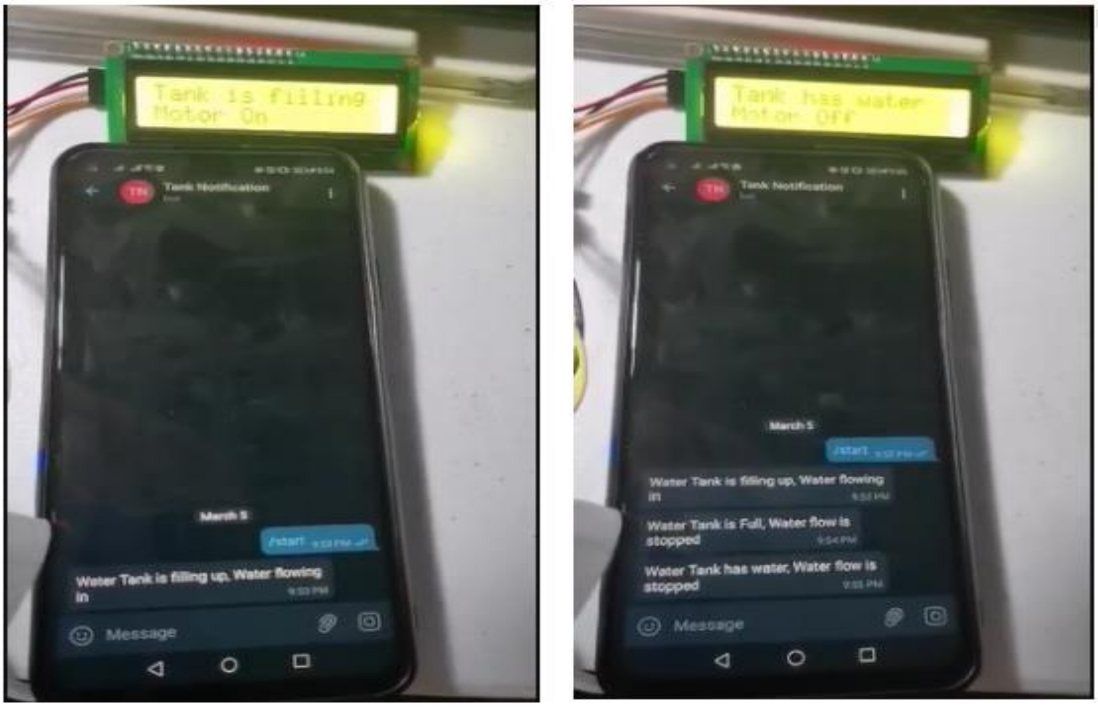
**"XXXXXXXXX:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX"**

**WiFiClientSecure client;**

**UniversalTelegramBot bot(BOTtoken, client);** These lines pass a Bot Token and an SSL Client. **#define CHAT_ID "1681147475" bot.sendMessage(CHAT_ID, "Water Tank Bot started**

**up", "");** These lines pass defines the Telegram Chat ID and sends message using the Telegram bot to the Chat ID (user).

Figure 6. Snapshot of SwaTS notification to a mobile device




4. User evaluation. Upon completion of SWaTS programming, it is connected to the water source for functional testing. In testing, the proponents will observe to answer the following questions:

- Can SWaTS CLOSE the solenoid valve when the water reaches the FULL level?
- Can SWaTS notify the owner about the water level in the tank

White Box Testing was implemented on the prototype. White Box Testing is a software testing method in which the internal structure/ design/ implementation of the item being tested is known to the tester (GeeksforGeeks, 2020). The test included Sensor workload Specification (see Table1). The water level sensors will be tested according to different states being: High or Low. High means there is water detection while Low means no water detection. For each of these states, the actuator is triggered to open the gate valve/motor and fill the tank with water.

Table 1. State transition table for SwaTS Whitebox Testing

| SF | SE | TRIGGER | NOTIFICATION | MOTOR/VALVE STATE |
|---|---|---|---|---|
| LOW | LOW | 0 | TANK IS FULL | OFF |
| LOW | HIGH | 0 | N/A | N/A |
| HIGH | LOW | 0 | TANK IS FILLING UP | ON |
| HIGH | HIGH | 0 | TANK IS EMPTY | ON |
| LOW | LOW | 1 | TANK IS FULL | OFF |
| LOW | HIGH | 1 | N/A | N/A |
| HIGH | LOW | 1 | TANK HAS WATER | OFF |
| HIGH | HIGH | 1 | TANK IS EMPTY | ON |

Legend: SE – Sensor Empty, SF – Sensor Full, Sensor Low – Water Detected, Sensor High – Water Not Detected

5. Refining prototype. If the user is not satisfied with the current prototype, refinements are made according to the user's feedback and suggestions. This phase will not be over until all the requirements specified by the user are met. Once the refinements are done and the user accepts the outcome with the prototype, a final system is developed based on the approved final prototype.

6. Implement Product and Maintain. When the final system is developed based on the final prototype, it is thoroughly tested and deployed to production or operation. The system undergoes routine maintenance for minimizing downtime and preventing large-scale failures.

6.1. **Design and Implementation Constraints**

The proposed SWaTS would be implemented using Arduino IDE for microcontroller unit programming. Programmable components like the non-contact water level detection sensors and the electric solenoid valve will be integrated according to its specifications. The design however, is constrained with the eventual face out of the programmable components in the market. In this case, the design would have to be upgraded and the code revised. The rest of the components like water pipes and fittings will remain as is without the need to worry about upgrading.

6.2. Assumptions and Dependencies

- SWaTS components are always connected
- User has access to SWaTS for monitoring purposes
- SWaTS is connected to a WiFi that has access to the Internet for notification purposes.
- User has a computer or mobile device to be able to receive notification using the Telegram app.
- The free open source Telegram app can be installed on a computer or mobile device.
- Appropriate and compatible hardware components are available for replacement and maintenance.
- User is capable of using the computer.

- The tank is not leaking.
- There is normal water pressure from the source.

C. Respondents of the Study.

The respondents of the survey include households in Brgy. 85 San Jose, Tacloban City. The 2015 Census of Population Report No.1-L entitled Population by Province, City, Municipality, and Barangay in Region VIII - Eastern Visayas reported Brgy. 85 San Jose as having 317 number of households (Philippine Statistics Authority, 2017). To get the sample of the population, the study will apply a stratified sampling method. The respondents will be grouped according to households with water tanks and households without water tanks. Since there are very few households with water tank, the researchers decided to use a disproportionate sample size that is 1:2 ratio of respondents without water tank to respondents with water tank. Thus, of the total respondents, ten (10) respondents composed the group of households with water tank, while five (5) respondents composed the group of households without water tank. In disproportionate sampling, the sample sizes of each stratum are disproportionate to their representation in the population as a whole. This method is preferred if the subject of the study is an underrepresented subgroup whose sample size would otherwise be too low to allow you to draw any statistical conclusions. (Thomas, 2020).

D. Data Gathering Instruments

This section discusses the instrument used in gathering responses from selected respondents. See Annex "A" for the survey instrument. To collect responses on household observations and/or experiences with domestic water collection, the researchers made use of a self-made 5-point Likert Scale survey questionnaire where respondents express their degree of agreement to each of the situation or statement by choosing one of the five-point scale being Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D) and Strongly Disagree (SD). Strongly Agree (SA) is assigned the highest scale of five (5), while SD assigned the lowest scale of 1. The instrument was modified after it was validated to correct identified errors in some items of the questionnaire. The same questionnaire was administered to both groups of respondents in a walk-in survey at the locale of the study.

E. Statistical Treatment of Data

The survey results are analyzed by examining the frequency distribution of the respondents' answers. (Rickards, Magee, & Artino, Jr., 2012). This method is especially useful for determining the demography of our respondents and determining their water source and water use. Examining the frequency distribution also allowed us to assess their observations and experiences with their current water collection method. Statistical analysis will not be used in this research. Qualitative research is not part of statistical analysis. That's because the results can't be tested to see if they are statistically significant (i.e.

to see if the results could have occurred by chance) (Glen, 2021). Qualitative analysis will be used to get the respondents point of view of the subject matter.

## 5 RESULTS AND DISCUSSION

The study sought to answer the following questions:

● How can empty water tanks be filled in without the need to physically access the tank?

● How can tank water waste be reduced?

● Can the Smart Water Tank System (SWaTS) efficiently reduce if not eliminate overflowing of tanks?

● Can the Smart Water Tank System (SWaTS) efficiently perform real-time monitoring of water level in the tank?

● Is the Smart Water Tank System usable to households in Tacloban City?

The product of the study was designed and built using WIFI-based microcontroller unit (MCU) connected with sensors that detects the water level in the tank. When the water level data sent by the sensors tells the MCU that the tank is FULL, the MCU directs the Solenoid valve that is normally OPEN to automatically CLOSE. This way, the user need not access the tank to turn if OFF. With SWaTS mechanism, and as observed from the Whitebox testing (see Table 2 – Results of SWaTS Whitebox Testing), it can efficiently eliminate overflowing of tanks, and it is capable of real-time water level monitoring of the water tank. It is therefore tantamount to say that SWaTS can help reduce wasting of water.

Table 2. Results of SWaTS Whitebox Testing

| Input | | | Expected Output | | | Actual Output | | |
|---|---|---|---|---|---|---|---|---|
| SF | SE | Trigger | Notification | Motor/Valve | Trigger | Notification | Motor/Valve | Trigger |
| Low | Low | 0 | Tank is Full | OFF | 1 | Tank is Full | OFF | 1 |
| Low | High | 0 | N/A | N/A | N/A | N/A | N/A | N/A |
| High | Low | 0 | Tank is filling up | ON | N/A | Tank is filling up | ON | N/A |
| High | High | 0 | Tank is empty | ON | N/A | Tank is empty | ON | N/A |
| Low | Low | 1 | Tank is Full | OFF | N/A | Tank is Full | OFF | N/A |
| Low | High | 1 | N/A | N/A | N/A | N/A | N/A | N/A |
| High | Low | 1 | Tank has water | OFF | N/A | Tank has water | OFF | N/A |
| High | High | 1 | Tank is empty | ON | 0 | Tank is empty | ON | 0 |

Legend: SE – Sensor Empty, SF – Sensor Full
Sensor Low = Water Detected
Sensor High = Water Not Detected
Trigger 0 = From Empty, Trigger 1 = From Full

## 6 CONCLUSIONS

To answer our research question of how an empty water tank can be filled in without the need to physically access the tank? The implemented prototype is able to automate water collection from the tap distributed by the local water district. It successfully eliminated wasting of water, and it prevented water tank overflow, the White Box test on SWaTS proved all of its features to be functional. All components are operational. Overall, the product contributes to a valuable amount of conservation over the world's life-giving resource which is water.

## ACKNOWLEDGEMENT

The researchers are deeply grateful to our research consultant Mr. Robert S. Raagas, BSEE Divine Word University of Tacloban for the valuable inputs on the overall concept of the study. The study came into fruition through the recommendations of the panel of critics namely: Dr. Micheline A. Gotardo (Chairman), and members: Prof. Devine Grace D. Funcion, and Prof. Dennis Tibe. Their valuable inputs shaped and resulted in significant improvements of this study.

The output is a requirement for completion of the course Systems Analysis and Design for the first semester of school Year 2021-2022, under the scholarly tutelage and encouragement of our respected professor Rommel Verecio DM-HRM, JD**.** We thank God above all for sustaining us throughout this endeavor.

## REFERENCES


Arduino. (2021). *What is Arduino?* Retrieved April 10, 2021, from Arduino Getting Started Guide: https://www.arduino.cc/en/Guide

Definitions.net. (n.d.). *Water Supply in the Philippines.* Retrieved March 10, 2021, from https://www.definitions.net/definition/water+supply.

DFRobot.com. (n.d.). *Non-contact Liquid Level Sensor XKC-Y25-T12V SKU SEN0204.* Retrieved March 05, 2021, from DFRobot: https://wiki.dfrobot.com/Non-contact_Liquid_Level_Sensor_XKC-Y25-T12V_SKU__SEN0204

ElShafee, A., & Hamed, K. A. (2012, August). Design and Implementation of a Wifi based Home Automation System. *World Academy of Science, Engineering and Technology International Journal of Computer and Information Engineering, 6*(8), 2177. Retrieved from https://www.researchgate.net/publication/230883124_Design_and_Implementation_of_a_WiFi_Based_Home_Automation_System

esp32.net. (n.d.). *The Internet of Things With ESP32.* Retrieved March 10, 2021, from http://esp32.net/

GeeksforGeeks. (2020, August 5). *Differences between Black Box Testing vs White Box Testing.* Retrieved April 10, 2021, from GeeksforGeeks: https://www.geeksforgeeks.org/differences-between-black-box-testing-vs-white-box-testing

Glen, S. (2021, April 5). *Research Methods: Qualitative Research and Quantitative Research*. Retrieved from StatisticsHowTo.com: Elementary Statistics for the rest of us!: https://www.statisticshowto.com/research-methods-qualitative-research-and-quantitative-research/

Guru99 Tech Pvt Ltd. (2019, November 27). *Prototyping Model in Software Engineering: Methodology, Process, Approach.* Retrieved March 10, 2021, from Guru99: https://www.guru99.com/software-engineering-prototyping-model.html

HiSoUR.com. (n.d.). *Water Supply in the Philippines.* Retrieved March 10, 2021, from https://www.hisour.com/water-supply-in-the-philippines-37203/

hweitugroup.com. (2021). Retrieved March 05, 2021, from hweitugroup.com: https://www.hweitugroup.com/index.php

iot-now.com. (2020, June 10). IoT and home automation: What does the Future Hold? *IoT Now Magazine*. Retrieved from https://www.iot-now.com/2020/06/10/98753-iot-home-automation-future-holds/

Iqbal, H. (2019, October 28). *How To Make Smart Home Automation System Using ESP32 Module?* Retrieved March 10, 2021, from https://appuals.com/how-to-make-smart-home-automation-system-using-esp32-module

Nishmitha, Shetty, S., Kotari, D., Shetty, P., & G, S. (2021). Water Tank Monitoring System. *International Journal of Engineering Research and Technology (IJERT), 7*(8), 4. Retrieved from https://www.ijert.org/Water-Tank-Monitoring-System

Philippine Statistics Authority. (2017, April 12). *Highlights Of The 2015 Census Results For Tacloban City*. Retrieved April 10, 2021, from rsso08.psa.gov.ph: http://rsso08.psa.gov.ph/sites/default/files/Special_Release_POPCEN_ISSN2017R0837-12_TaclobanCity.pdf

Richey, R. C., & Nelson, W. A. (2001, August 1). Developmental Research. *The Handbook of Research for Educational Communications and Technology*. Retrieved from http://members.aect.org/edtech/ed1/42/index.html

Rickards, G. M., Magee, C. M., & Artino, Jr., A. R. (2012). You Can't Fix by Analysis What You've Spoiled by Design: Developing Survey Instruments and Collecting Validity Evidence. *Journal of Graduate Medical Education*, 407–410.

Riyaz, J. (2017). *How to Connect I2C Lcd Display to Arduino Uno.* Retrieved March 05, 2021, from Instructables Circuits: https://www.instructables.com/How-to-Connect-I2C-Lcd-Display-to-Arduino-Uno/

Santos, R., & Santos, S. (2013-2021). *Telegram: Control ESP32/ESP8266 Outputs (Arduino IDE).* Retrieved March 08, 2021, from RandomNerdTutorials.com: https://randomnerdtutorials.com/telegram-control-esp32-esp8266-nodemcu-outputs/

Sayyed, A., & Aziz, M. W. (2021, March). Towards an Autonomous and Smart Water Tank System. *International Journal of Emerging Trends in Engineering Research, 9*(3), 244. Retrieved from http://www.warse.org/IJETER/static/pdf/file/ijeter15932021.pdf

Shelly, G. B., Cashman, T. J., & Rosenblatt, H. J. (2005). *Systems Analysis and Design* (6th ed.). Thomson Course Technology.

Telegram FZ-LLC. (n.d.). *Bots: An introduction for developers.* Retrieved from Telegram.org: https://core.telegram.org/bots

The World Bank Group. (2003, December). Water Quality. *Philippines Environment Monitor 2003*, 52. Retrieved from http://documents1.worldbank.org/curated/en/144581468776089600/pdf/282970PH0Environment0monitor.pdf

Thomas, L. (2020, September 18). *How to use stratified sampling.* Retrieved May 5, 2021, from Scribbr.com: https://www.scribbr.com/methodology/stratified-sampling/

Villanueva, R. (2012, March 23). 70 Percent of Water in Phl Wasted. *Philippine Star Global*. Retrieved from https://www.philstar.com/headlines/2012/03/23/789648/70-percent-water-phl-wasted

World Bank. (2003, December). Water Quality. *Philippines: Environment Monitor 2003*, 51. Retrieved from http://documents1.worldbank.org/curated/en/144581468776089600/pdf/282970PH0Environment0monitor.pdf

World Bank. (2007, February 5). Identifying Elements of Sustainability – Lessons Learned from Rural Water Supply Projects in the Philippines. *Water and Sanitation Program - East Asia and the Pacific*, 16. Retrieved from https://web.archive.org/web/20071024080809/http:/www.wsp.org/filez/pubs/319200740400_identifyingelementsofsustainability.pdf