Realtime and Liquid Tank Volume Monitoring Based on Internet of Things

Andrizal [a,1], Dedi Kurniadi [a,2], Nadia Alfitri, [a,3*], Humaira [b,1], Fiona Novia Hafsyah[a,4]

[a] *Department of Electrical Engineering, Padang State Polytechnic, Indonesia*
[b] *Department of Information Technology, Padang State Polytechnic, Indonesia*
E-mail: andrizal@pnp.ac.id, dedikurniadi@pnp.ac.id nadiaalfitri@pnp.ac.id, humaira@pnp.ac.id, fionahafsyah@gmail.com
**corresponding author*

A B S T R A C T S

An underground tank is a type of tank installed by burying it on the ground. Underground tanks in the form of a storage area with large dimensions for either liquid or gas, especially BBM (fuel) which is stored underground at Public Fuel Filling Stations his (SPBU). The supply of liquid in this tank really needs to be maintained to meet the need for liquid. In order to be able to monitor the volume of liquid in the underground tank, a device was designed that can monitor the volume of liquid in the tank remotely. This device uses an ultrasonic sensor that can detect the volume of liquid that has been converted from the distance detected by the sensor, and uses Wemos D1 mini on the device and ESP32 on the server as a microcontroller that sends data from the reading process to smartphones and websites. The device works on ultrasonic sensor which can sense the distance and with some calculation it detects how much liquid is sensed as a volume and employs a Wemos D1 mini on the side of device and an ESP32 on the server part as a microcontroller that sends reading data to smartphones and websites. The smartphone displays show liquid volume and distance shown by the sensor while in the server display distance is plotted against time in graphical form. Test results reveal that this device can remotely detect underground tank liquid volume using smartphones or websites with a success rate of 72.35%. This failure rate of 27.65% is caused by curved tanksurface and misplacement of the tank.

K E Y W O R D S

Underground Tank, Liquid, Monitoring, Ultrasonic Sensor, Wemos D1 Mini, ESP32, Smartphone, Website.

1. INTRODUCTION

Tanks are one of the important components in various industries, such as oil and gas, chemical, petrochemical and others. Tanks have a function to store (accumulate) water, gas, oil, and other metal fluids [1]. Underground tanks are one type of storage tank that is installed by placing the tank in or below the ground surface, this type of tank has a horizontal cylindrical shape. This tank is commonly used at Public Fuel Filling Stations (SPBU) which function to store supplies of Fuel Oil (BBM) [2].

The supply of fluids in the underground tank must be maintained so that fluid needs can be met. Like a gas station operator who must monitor the supply of fuel fluids in the underground tank and ensure that the tank is refilled before the fuel fluid runs out. Therefore, a device was designed that can detect the volume of fluid in the underground tank remotely in real time.

The design of monitoring the volume of liquid in the underground tank uses an ultrasonic sensor located at the top of the underground tank to facilitate reading the volume of liquid in the tank. In addition, using Wemos D1 mini and ESP32 which can transmit data. The results are in the form of a display of distance and volume detected by the ultrasonic sensor on a smartphone designed using MIT App Inventor, and a display of distance on the website in the form of a graph. This website can be used by distribution centers such as PT. Pertamina Pusat which will deliver fuel supplies to gas stations. With this display, officers can monitor the volume of liquid in the underground tank in real time and there is also a notification on the smartphone when the liquid is running low.

2. RESEARCH METHODOLOGY

2.1. Block Diagram System

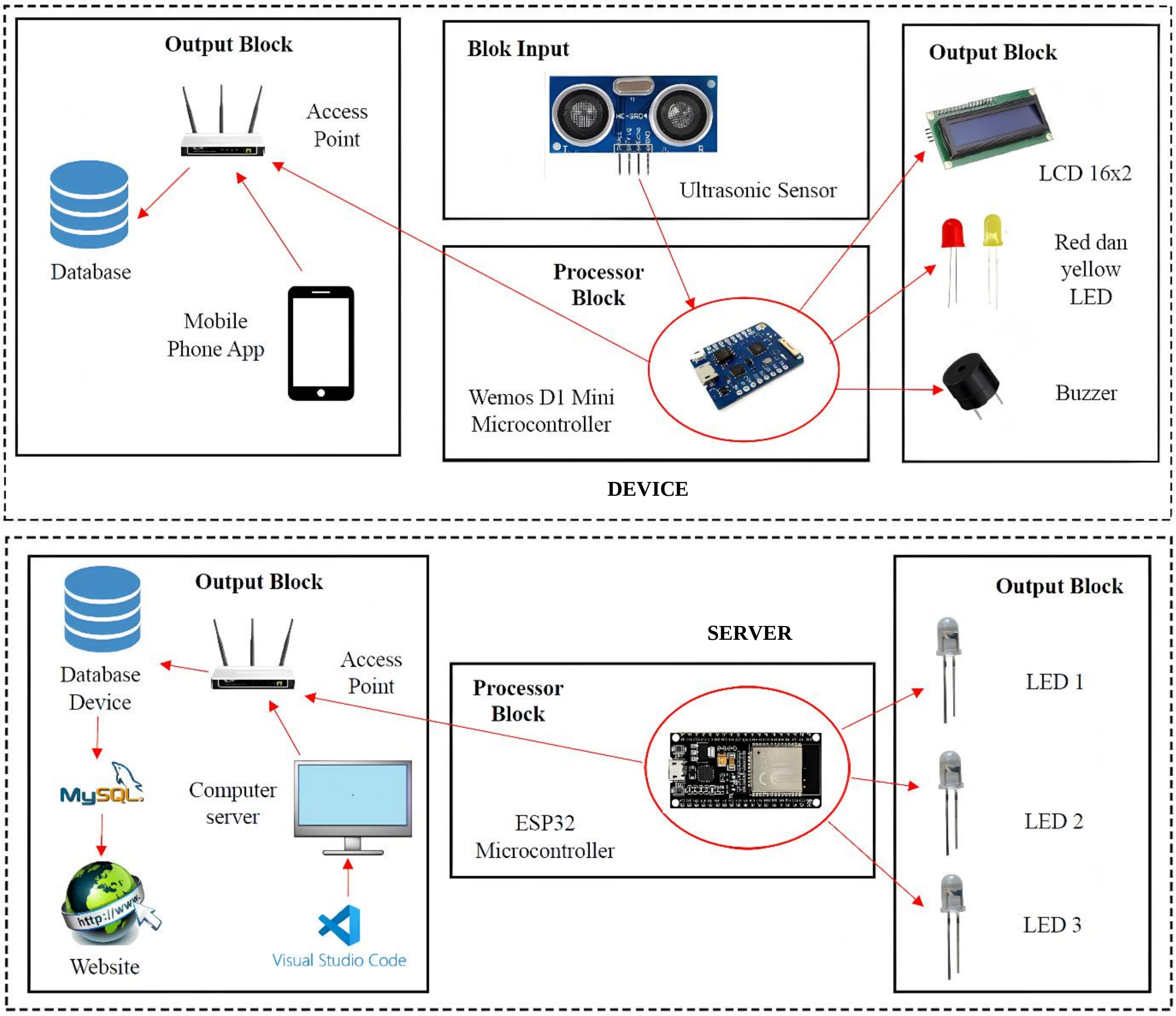


FIG 1. Block Diagram

Figure 1 is a block diagram with input on the device consisting of ultrasonic sensors. The output from this sensor is processed using a wemos D1 mini microcontroller. The data processed by the wemos D1 mini is sent to the database and also produces a display on the smartphone, the display on the smartphone is in the form of distance measurements and liquid volume that has been converted from the distance detected by the sensor. From the database it is processed by the ESP32 microcontroller to produce an output display on the website. The display on the website is in the form of a distance detected by the sensor in the form of a graph.

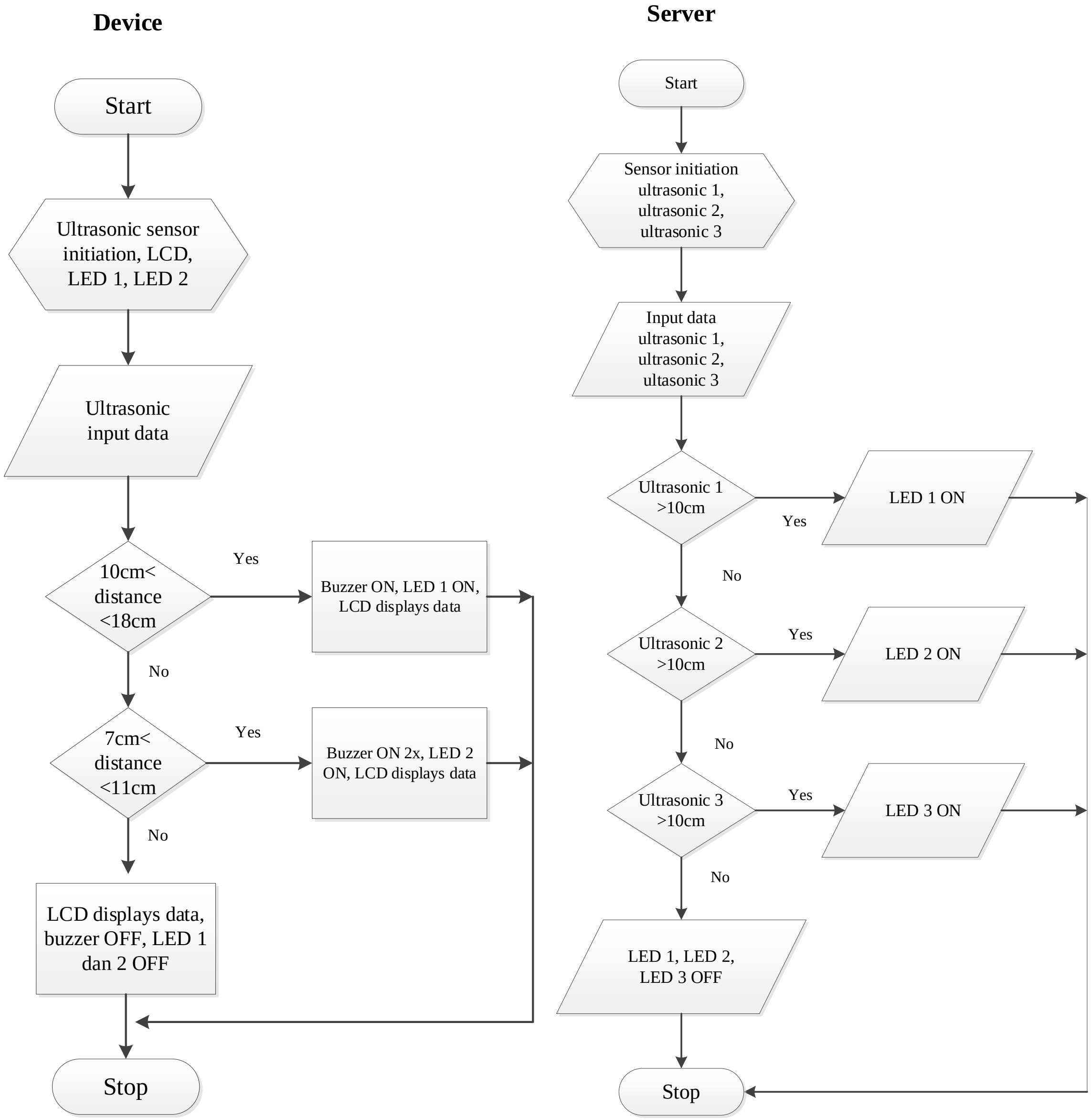


FIG 2. Flowchart

2.2. Ultrasonic Sensor

Ultrasonic sensors are devices that operate by utilizing the reflection of sound waves to identify the presence of a particular object in front of them [3]. Ultrasonic sensors are sensors that convert physical quantities (sound) into electrical quantities. Ultrasonic sensors work by reflecting sound waves and are used to detect the presence of a particular object or thing [4], [5], [6]. Ultrasonic waves are acoustic waves that have a frequency of 20kHz to approximately 20 MHz. Ultrasonic sensors are placed above underground tanks to detect the distance of the liquid surface in the tank. The results of this distance measurement are converted into the volume of liquid available in the underground tank.

2.3. Wemos D1 Mini

The Wemos microcontroller is one of the boards that can function with Arduino, especially for projects that carry the concept of the Internet of Things (IOT) [7]. In this wemos there is still a wifi module based on ESP8266 which is used as an internet connection between Arduino and a smartphone or PC via a wifi network [8]. The main function of this wemos is a microcontroller board that can be connected to a wifi network. Therefore, this microcontroller can be used as an IOT device where sensor value readings can be sent via the internet with a Wifi network.

2.4. NodeMCU ESP32

The NodeMCU ESP32 is a low-power system on a chip (SoC) with Wi-Fi and dual-mode Bluetooth capabilities. The ESP32 has a CPU core and faster Wi-Fi, more GPIOs, and supports Bluetooth Low Energy [9]. There is WiFi that allows for Internet of Things applications with the ESP32 microcontroller. The ESP32 has a very complete chip that combines a processor, storage, and access to GPIO (all inclusive data age) [10]. The ESP32 functions as a microcontroller that can be used as a controller automatically according to the program created.

2.5. Formula for Calculating Liquid Volume

The underground tank has a physical form like a tube with a horizontal position. To find out the volume of liquid through the section area as follows [11].

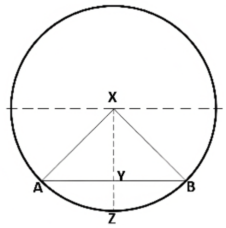


FIG 3. Variable on Circle

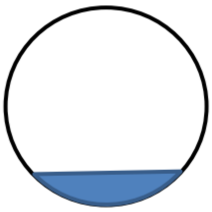
Area of circle = π x r^2
Volume of tank = area of circle x length of tank
Sector area of AZBX = x / 360 x Area of circle
Area of triangle ABX = AB x XY / 2
Segment area of AZB = Sector area of AZBX – Area of triangle ABX

If the measured liquid surface height is less than the radius of the submerged tank, as shown in Fig. 4.a, then the liquid volume can be calculated using the following equation (1):

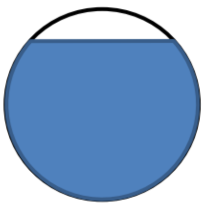
Volume of liquid = Area of Section x Length of Tank

If the measured liquid surface height exceeds the radius of the underground tank, as shown in Fig. 4.b, then the liquid volume can be calculated using the following equation (2):

Volume of liquid = Tank Volume – (Segment Area x Tank Length)



a. Liquid level is less than tank radius



b. The liquid level exceeds the radius of the tank

FIG 4. Illustration of Calculation of Liquid Volume in Underground Tanks

2.6. MIT App Inventor

MIT App Inventor is a visual block-based programming language. MIT APP Inventor is an IDE or integrated Development Environment that is useful in helping to build android applications without having to be experienced in the world of programming, the application is open source based [12], [13], [14]. MIT APP Invertor is used to create applications that can display the distance and volume of liquid detected by the ultrasonic sensor displayed on the smartphone screen. This application can be used by connecting the smartphone to Wi-Fi (access point).

2.7. Website

A website is a collection of pages containing information in the form of digital data provided via an internet connection. The website displays the distance readings detected by the ultrasonic sensor in the form of a graph. This website can be used by connecting the computer to the internet (access point) and also connecting to the xampp application [15].

2.8. *Hardware Design*

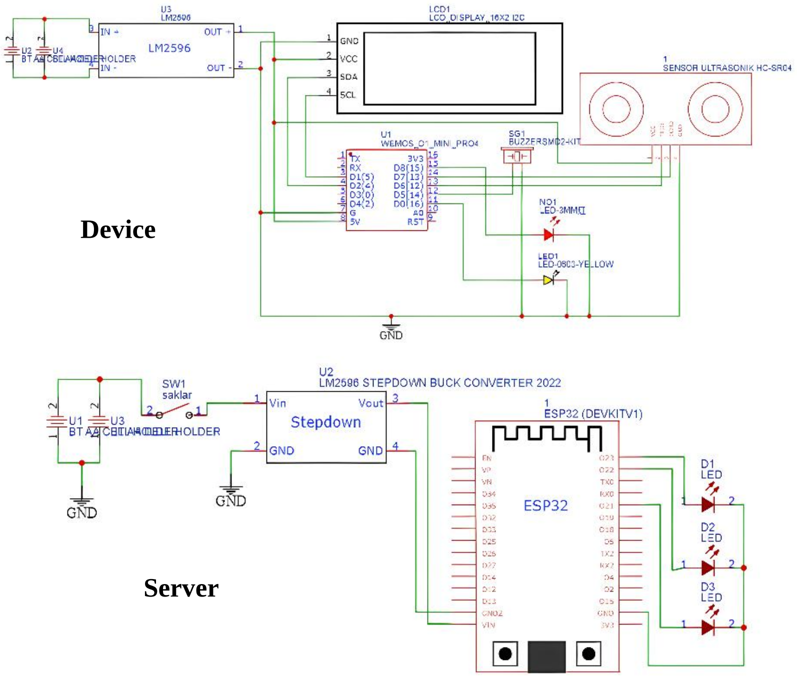


FIG 5. Skematic diagram for component connection and Design User

3. RESULTS AND DISCUSSION

The purpose of this research is to create a system that can detect the availability of fluid in the tank in real time remotely. This system can also be applied to Pertamina distribution centers that will send fuel refills without waiting for an order letter from the relevant gas station to reduce delays in delivery. This system uses a prototype tank with a horizontal position, using the main component of an ultrasonic sensor that can detect the volume of fluid that has been converted from the distance detected by the sensor and also ESP32 as a microcontroller that sends data in real time. This tank has a maximum capacity of ± 5 liters. The shape and size of the tank used can be seen in Fig. 6.

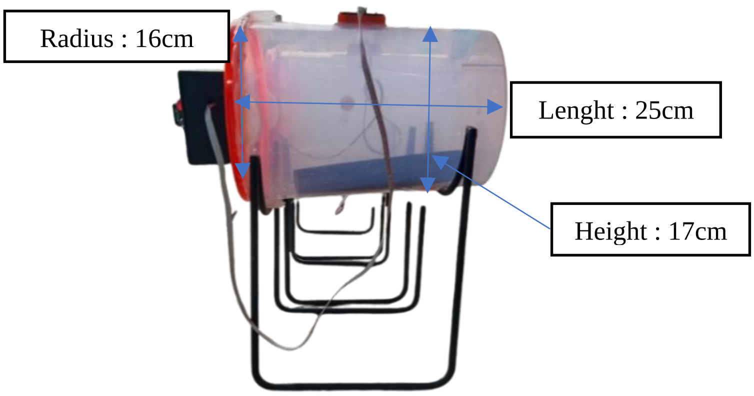


FIG 6. Tank Prototype

This test uses pertalite fuel. The test is carried out by inserting the fuel liquid into the tank starting with a volume of 1 liter to 5 liters using a measuring cup. The volume data read by the ultrasonic sensor and displayed on the smartphone is compared to the measuring cup.

The test results from the display on the smartphone can display the distance detected by the ultrasonic sensor and also the volume of liquid that has been converted from the distance detected by the sensor. After conducting the test, the following data was obtained which can be seen in table 1.

TABLE 1. Smartphone Testing

Ultrasonic Sensor (cm)			Liquid Volume (mL)			Measuring Cup (mL)	Error Percentage (%)
1st Tank	2nd Tank	3rd Tank	1st Tank	2nd Tank	3rd Tank		
17	17	17	0	0	0	0	0
16	16	16	2.976	2.976	2.976	1.000	66,4
14	14	14	2.604	2.604	2.604	2.000	23,3
11	11	11	2.064	2.064	2.064	3.000	45,3
8	8	8	3.535	3.535	3.535	4.000	13,2
5	5	5	4.093	4.093	4.093	5.000	17,8
						Error Average	27,65

The test results from the display on the website in real time and MYSQL which can store data detected by the ultrasonic sensor every 3 seconds. After conducting the test, the following data was obtained which can be seen in table 2.

TABLE 2. Website Testing

Time	Ultrasonic Sensor (cm)			Liquid Volume (mL)
	1st Tank	2nd Tank	3rd Tank	
1st Tank				
2024-07-12 14:59:17	17	17	18	0
2024-07-12 14:59:20	17	17	18	0
2024-07-12 15:00:07	16	17	18	1.000
2024-07-12 15:00:10	16	17	18	1.000
2024-07-12 15:09:47	14	17	18	2.000
2024-07-12 15:09:50	14	17	18	2.000
2024-07-12 15:17:17	11	17	18	3.000
2024-07-12 15:17:20	11	17	18	3.000
2024-07-12 15:21:37	8	17	18	4.000
2024-07-12 15:21:40	8	17	18	4.000
2024-07-12 15:25:43	5	17	18	5.000
2024-07-12 15:25:46	5	17	18	5.000
2nd Tank				
2024-07-12 15:47:17	3	17	18	0
2024-07-12 15:47:20	3	17	18	0
2024-07-12 15:48:23	3	16	18	1.000
2024-07-12 15:48:26	3	16	18	1.000
2024-07-12 15:51:40	3	14	18	2.000
2024-07-12 15:51:43	3	14	18	2.000
2024-07-12 15:57:36	3	11	18	3.000
2024-07-12 15:57:40	3	11	18	3.000
2024-07-12 15:58:53	3	8	18	4.000
2024-07-12 15:58:56	3	8	18	4.000
2024-07-12 16:00:00	3	5	18	5.000
2024-07-12 16:00:03	3	5	18	5.000
3rd Tank				
2024-07-12 16:06:40	3	0	17	0
2024-07-12 16:06:43	3	0	17	0
2024-07-12 16:12:57	3	0	16	1.000
2024-07-12 16:13:00	3	0	16	1.000
2024-07-12 16:14:50	3	0	14	2.000
2024-07-12 16:14:53	3	0	14	2.000
2024-07-12 16:16:07	3	0	11	3.000
2024-07-12 16:16:10	3	0	11	3.000
2024-07-12 16:18:30	3	0	8	4.000

2024-07-12 16:18:33	3	0	8	4.000
2024-07-12 16:21:03	3	0	5	5.000
2024-07-12 16:21:06	3	0	5	5.000

4. Conclusions

From the results of the system test, this device can read the distance and volume of liquid in the underground tank that has been converted from the distance detected by the ultrasonic sensor. In the comparison test of the volume of liquid on the device with a measuring cup, there was a failure with an average of 27.65% and testing on the website can display data in real time and stored in MYSQL every 3 seconds. The cause of the device failure is due to the influence of the curve on the surface of the underground tank and the position of the underground tank which is not flat enough.

Reference

[1] H. A. Ibrahim and H. S. Syed, "Hazard Analysis of Crude Oil Storage Tank Farm," Int J Chemtech Res, vol. 11, no. 11, pp. 300–308, 2018, doi: 10.20902/IJCTR.2018.111132.

[2] V. A. Zhmud, N. O. Kondratiev, K. A. Kuznetsov, V. G. Trubin, and L. V Dimitrov, "Application of ultrasonic sensor for measuring distances in robotics," J Phys Conf Ser, vol. 1015, p. 032189, May 2018, doi: 10.1088/1742-6596/1015/3/032189.

[3] O. Appiah, E. Quayson, and E. Opoku, "Ultrasonic sensor based traffic information acquisition system; a cheaper alternative for ITS application in developing countries," Sci Afr, vol. 9, p. e00487, Sep. 2020, doi: 10.1016/j.sciaf.2020.e00487.

[4] N. I. Abdulkhaleq, I. J. Hasan, and N. A. J. Salih, "Investigating the resolution ability of the HC-SRO4 ultrasonic sensor," IOP Conf Ser Mater Sci Eng, vol. 745, no. 1, p. 012043, Feb. 2020, doi: 10.1088/1757-899X/745/1/012043.

[5] W. Suryono, A. Setiyo Prabowo, Suhanto, and A. Mu'ti Sazali, "Monitoring and controlling electricity consumption using Wemos D1 Mini and smartphone," IOP Conf Ser Mater Sci Eng, vol. 909, no. 1, p. 012014, Dec. 2020, doi: 10.1088/1757-899X/909/1/012014.

[6] B. Naji, "Wemos-D1 and Raspberry Pi3 Based Smart Communication and Control of Home Appliances System," Muthanna Journal of Engineering and Technology, vol. 6, no. 1, pp. 29–44, Oct. 2018, doi: 10.18081/mjet/2018-6/29-44.

[7] T. Ethilu, A. Sathappan, and P. Rodrigues, "An Effective Time-Sharing Switch Migration Scheme for Load Balancing in Software Defined Networking," Journal of Advances in Information Technology, vol. 14, no. 4, pp. 846–856, 2023, doi: 10.12720/jait.14.4.846-856.

[8] C. Mihci and N. Ozdener Donmez, "Teaching GUI-Programming Concepts to Prospective K12 ICT Teachers: MIT App Inventor as an Alternative to Text-Based Languages," INTERNATIONAL JOURNAL OF RESEARCH IN EDUCATION AND SCIENCE, pp. 543–543, Jul. 2017, doi: 10.21890/ijres.327912.

[9] M. A. and S. Al-Omary, "Quizrevision: A Mobile Application using the Google MIT App Inventor Language Compared with LMS," International Journal of Advanced Computer Science and Applications, vol. 8, no. 6, 2017, doi: 10.14569/IJACSA.2017.080641.

[10] F. Liu et al., "A Real-Time Closed Tank Capacity Measurement Method for Liquid Volume Supporting the Internet of Things, Big Data and Intelligent Ship Supply Chain," in 2022 International Conference on Industrial IoT, Big Data and Supply Chain (IIoTBDSC), IEEE, Sep. 2022, pp. 311–316. doi: 10.1109/IIoTBDSC57192.2022.00064.

[11] V. B, S. P. S J, A. S, K. G, K. T, and M. S, "Measuring the Volume of Spherical Tank Using Load Cell," in 2023 International Conference on Energy, Materials and Communication Engineering (ICEMCE), IEEE, Dec. 2023, pp. 1–5. doi: 10.1109/ICEMCE57940.2023.10434055.

[12] D. S. Bhandare, V. S. Jape, H. H. Kulkarni, S. M. Mahajan, P. Sable, and Y. Pawar, "Automatic Liquid Level Control of Two Tank System using PLC," in 2024 International Conference on Intelligent Systems and Advanced Applications (ICISAA), IEEE, Oct. 2024, pp. 1–6. doi: 10.1109/ICISAA62385.2024.10828622.

[13] Y. Song et al., "Analysis of Influence of Baffle Number on Liquid Sloshing Characteristics in Tank," in 2019 2nd World Conference on Mechanical Engineering and Intelligent Manufacturing (WCMEIM), IEEE, Nov. 2019, pp. 113–116. doi: 10.1109/WCMEIM48965.2019.00029.

[14] O. Sierikova, E. Strelnikova, and K. Degtyariov, "Srength Characteristics of Liquid Storage Tanks with Nanocomposites as Reservoir Materials," in 2022 IEEE 3rd KhPI Week on Advanced Technology (KhPIWeek), IEEE, Oct. 2022, pp. 1–7. doi: 10.1109/KhPIWeek57572.2022.9916369.

[15] A. V Balakrishnaa and N. K. Arun, "Liquid Level Control of Interacting Coupled Spherical Tank System using PI and Fuzzy PI Controller," in 2022 3rd International Conference for Emerging Technology (INCET), IEEE, May 2022, pp. 1–5. doi: 10.1109/INCET54531.2022.9824570.