



Internet of Things

Volume Measurement System of Used Cooking Oil (UCO) Using Internet of Things and Web-Based System

Zulafirilian Koto¹, Arrya Anandika^{2*}, Yuta Sato³, Pramawahyudi⁴, Ronaldo Syahputra⁵

^{1,2,4}Department of Computer Engineering, Faculty of Information Technology, Andalas University, Indonesia

^{2,3}Graduate School of Science and Engineering, Ibaraki University, Japan

⁵Department of Information System, Faculty of Computer Science, Universitas Putra Indonesia YPTK Padang

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CORRESPONDENCE

Phone: +62 812 6618 171

E-mail: arrya.anandika@it.unand.ac.id

A B S T R A C T

One of the main issues is the discrepancy between the measured and actual oil volumes of used cooking oil (UCO). Using a measurement tank as the measuring medium and an ultrasonic sensor as the tool, a system was developed to automatically measure oil volume with high accuracy. This system allows users to continuously measure oil volume using a servo motor that directs the oil into a storage tank. The system is designed to notify the company and customers via an LCD display and website when the oil measurement is completed. The system successfully measures oil volume using the ultrasonic sensor, achieving an accuracy of 96.74% during implementation.

INTRODUCTION

Nowadays, oil is widely extracted from various natural resources, including both animal and plant sources, such as palm oil, canola, sunflower, algae, soybeans, peanuts, and others[1]. Oil production is carried out to meet human needs, such as daily consumption[2], fuel[1][3], renewable energy[4], and various other requirements. Specifically, oil is used for household needs, such as cooking[2][4][5][6].

Cooking oil is widely produced by various factories and companies to meet household needs. The quality of cooking oil is crucial to consumer health, as low-quality oil can have adverse health effects if consumed regularly[2]. Diseases such as diabetes, obesity, cancer, and other conditions may arise if cooking oil is consumed in excessive amounts[6]. Additionally, many merchants or business owners reuse cooking oil repeatedly to reduce production costs without considering the resulting decline in oil quality[5].

Studies show that Europe produces approximately 700,000 tons of used cooking oil (UCO) annually. Meanwhile, in some Asian countries, the annual production of used cooking oil reaches 40,000 tons[7]. In Australia, it reaches 50,000 tons annually.

Although many used cooking oil collection systems have been developed, whether manual[8] or technological[7][9], many people still dispose of used cooking oil improperly, such as into rivers, the ocean, or the ground, thereby polluting the environment[8]. In addition, used cooking oil is often disposed of in public sewer systems, which requires more extensive maintenance and increases water treatment costs[10].

Used cooking oil should no longer be used because it is carcinogenic[10] and unfit for human consumption. Additionally, the difference between used cooking oil and fresh cooking oil is clearly visible in both appearance and odor[6]. Therefore, this can be avoided.

Therefore, in addition to collection, efforts to recycle used cooking oil are also being made to protect the natural ecosystem. Various systems have been developed for both collection and recycling. One example of UCO recycling is its conversion into raw materials for household products, such as bar soap[10]. A study by the authors [10] Conducted education and training on used cooking oil recycling for housewives, with results showing that 80% of participants were able to accept and practice the methods.

In addition to training, many systems related to used cooking oil are being developed based on sensors[2][5][6][11][12][13][14]

and the Internet of Things (IoT)[7]. Using an electronic nose, the system can distinguish between fresh cooking oil and bleached waste cooking oil using machine learning algorithms, achieving 99% accuracy and 99.5% precision[6]. Another study discusses a prototype system for measuring peroxide concentration in cooking oil using a green laser, achieving 91.55% accuracy and 89.66% precision[5].

Another method is colorimetric titration to determine free fatty acids in cooking oil with 90.3% accuracy[11]. Another study involves the classification of cooking oil aromas using chemometric and e-nose methods, employing linear discriminant analysis (LDA) and artificial neural networks (ANN). The results show that the ANN method achieves 94% accuracy[15].

Research [7] relates to the development of an IoT-based used cooking oil collection system. This system utilizes an ultrasonic sensor, a solenoid valve, an ESP32 microcontroller, and an LCD screen. Using an ESP32, data can be transmitted in real time via the IoT system to the Blynk application. The developed system also features an alarm, schedule efficiency, and displays the collection process. This research successfully developed an efficient and effective cooking oil collection system.

Several previous studies on liquid-level and volume measurement systems for water tanks based on microcontrollers have also been published[16][17][18][19]. The first study uses ultrasonic sensors to detect water levels based on the principle of ultrasonic wave reflection. The research focuses only on specific water levels used to open and close the water valve with a servo motor. The accuracy of the sensor distance compared to the actual distance was not a major concern, as the ultrasonic sensor was only used within a specific range[17].

Another study presents a Prototype of a Water Tank Height Monitoring System, focusing on water-level measurement. In this study, the designed system shuts off the water when the level reaches a predetermined limit. However, this study's drawback is that it still uses a standard ultrasonic sensor, which is not waterproof, posing a risk of sensor damage from water splashes during tank filling. Waterproofing offers the advantage of minimizing potential damage to the sensor[20].

Based on the studies described, concerns about the accuracy of water-collection systems warrant attention, particularly regarding UCO. Specifically, measuring the volume of used cooking oil during collection is a critical component of subsequent steps, such as exchanging used cooking oil for cash, to ensure that neither consumers nor used cooking oil collectors are disadvantaged.

This study proposes a used cooking oil measurement and collection system that prioritizes accurate volume measurements. The developed system utilizes ultrasonic sensors and solenoid valves to measure the level and volume of used cooking oil. The measurement and collection tanks are designed separately to ensure accuracy, thereby preventing measurement errors and minimizing losses for both consumers and service providers. The system also uses IoT to display measurement and collection reports on a website easily accessible to providers.

METHOD

To meet the system requirements necessary for achieving the research objectives, the system to be developed must be designed in accordance with the identified functional and non-functional needs. The proposed system design is outlined as follows.

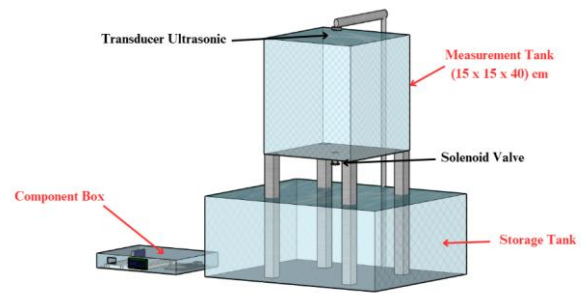


Figure 1. General System Design

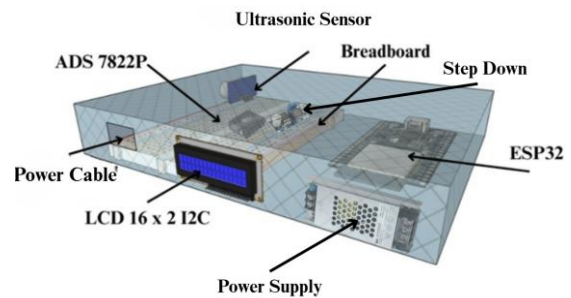


Figure 2. Component Box

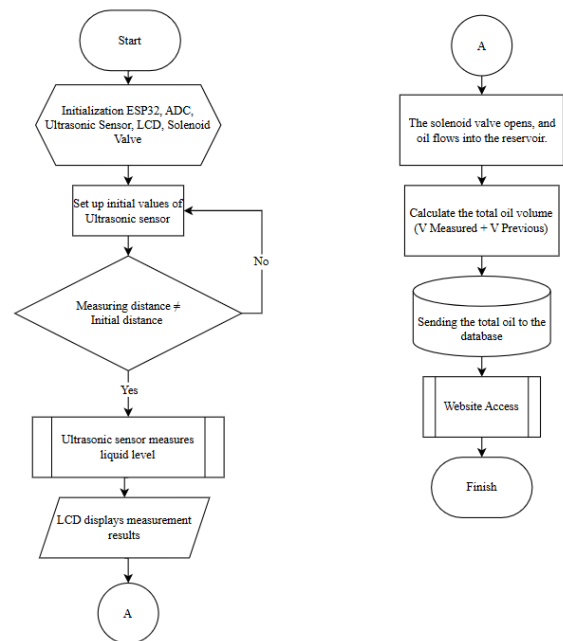


Figure 3. General System Design Flowchart

Figure 1 illustrates the system design, which consists of two tanks. The first tank serves as a measuring tank with a capacity of 90 m³. The measuring tank is located above the storage tank. In the measurement tank, there are two components: an ultrasonic transducer and a solenoid valve. The ultrasonic transducer detects ultrasonic waves to determine the oil's height and volume. The storage tank is used to hold the total volume of measured used cooking oil. Additionally, there is a box containing other components used in the system.

Figure 2 illustrates the components of the box, which include an ESP32 microcontroller, an ultrasonic sensor, an ADS7822P analog-to-digital converter (ADC), an LCD display, and a power cable. An ultrasonic sensor measures the wave signal from the transducer positioned above the tank. ESP32 processes this input to generate commands for calculating height and volume, and to

relay information to the output component. The readings from the input component are displayed on an LCD. Ultimately, the comprehensive measurement results will be recorded and made available on a website in real-time.

This process design comprises two primary components: hardware design and software design. These components elucidate the system's operational framework for processing input data to generate the desired output. The design is implemented through programming on a microcontroller, which serves as the system's primary control component. This software design encompasses the various stages of the system's operational process to be developed.

The flowchart presented delineates a systematic methodology for the design and operation of a measuring device intended to determine the height and volume of oil within a storage tank. The process begins with system initialization, including configuring the ultrasonic sensor and associated hardware components. Following initialization, the ultrasonic sensor is utilized to measure the oil level in the tank. If the sensor reading remains identical to the initial measurement, the system instructs the sensor to repeat the measurement to ensure accuracy and reliability. In contrast, a deviation from the initial reading is interpreted as an indication that the tank has been refilled, thereby allowing the oil measurement process to proceed.

Once the oil height has been successfully measured, the corresponding data are displayed on an LCD interface and simultaneously transmitted to the database for storage and further processing. Subsequently, the solenoid valve is activated to enable controlled oil transfer from the measurement tank to the storage tank. Finally, the cumulative oil volume is calculated, recorded in the database, and made accessible via a web-based interface for monitoring and documentation.

In Figure 4, when the measurements obtained from the ultrasonic sensor differ from the initial sensor settings, this discrepancy signifies that the tank has been filled. Subsequently, the sensor initiates the oil measurement process. The height measurement is accomplished by subtracting the ultrasonic sensor measurement results (a) from the total tank height (T). The resulting value is then multiplied by (-1) to determine the actual oil height. Once the oil height is established, the oil volume is calculated by multiplying the tank length (P), tank width (L), and oil height (T). Finally, the oil volume measurement results are transmitted to the website for real-time display.

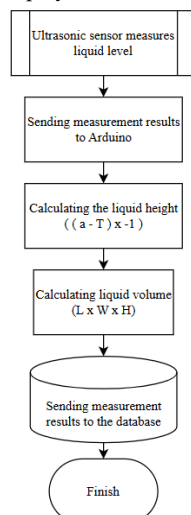


Figure 4. Flowchart of the Liquid Measurement Sub-Process

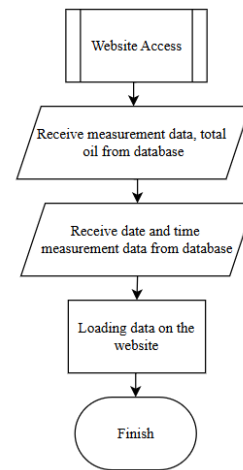


Figure 5. Flowchart of the Website Access Sub-Process

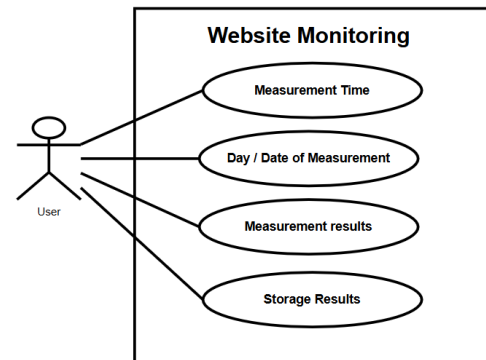


Figure 6. Use-case Diagram

In Figure 5, once the measurement data and total oil have been saved, the website is programmed to automatically present the data in real time, organized by measurement date and time, while also loading the pre-designed data display.

Website design serves a critical function by enabling users to monitor oil reservoirs remotely. Through the website, users can access monitoring results, thereby optimizing human resource allocation. During the website design phase, a thorough discussion should be held about user activities on the website and the output generated. This design process encompasses several sub-designs, including the Use Case Diagram, the Activity Diagram, and the website's interface design. The following elaborates on various components essential for the effective design of a website within a system.

Figure 6 presents a use-case diagram for the oil tank measurement website, which serves the public seeking to assess the volume of their used cooking oil. The website offers various functionalities for users, including the ability to view the current time, day, date, and measurement results, as shown in Figure 7. Additionally, the website features a section that displays the cumulative measurements recorded in the measurement tank, specifically within the storage results feature.

UCO Monitoring				
Measurement Tank				
	No.	Date (dd/mm/yyyy)	Time	Volume (Liter)
MEASUREMENT	1.	20/12/2023	14.35	2.1 Liter
	2.	20/12/2023	16.40	1.3 Liter
STORAGE	3.			
	4.			
	5.			

(a)

UCO Monitoring				
Storage Tank				
MEASUREMENT	No.	Date (dd/mm/yyyy)	Time	Volume (Liter)
	1.	20/12/2023	14.35	2.1 Liter
	2.	20/12/2023	14.40	3.4 Liter
STORAGE	3.			
	4.			
	5.			

(b)

Figure 7. Website's interface design; (a) Measurement tank; (b) Storage tank

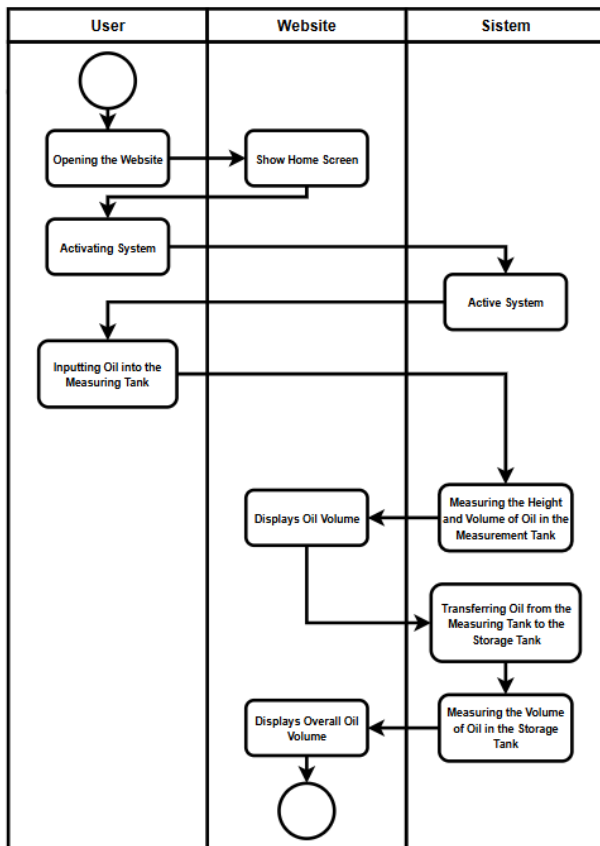


Figure 8. Activity Diagram

Figure 8 presents an activity diagram illustrating the oil tank measurement system. This diagram includes three key participants: the user, the website, and the system. The process begins when the user activates the system. Subsequently, the user accesses the website to view its initial display. Following this, the user inputs oil into the measurement tank for assessment. Once the measurement is complete, the website will display the measurement results along with the timestamp. Thereafter, the system will transfer the measured oil to the storage tank. Ultimately, the system will calculate the total volume of oil and display this information on the website's storage tank section.

RESULTS AND DISCUSSION

The implementation of the system is conducted with the objective of determining whether the designed system operates effectively and to assess various indicators of the system's success. This phase encompasses hardware implementation, which includes the

system's external appearance and the arrangement of components within the device. It also involves software development, specifically programming the microcontroller and developing the associated website. Comprehensive system implementation, as shown in Figure 8, facilitates the overall workflow, from the device's initial power-up to the generation of the specified output. The hardware implementation describes the specific state of the hardware components that comprise a system, detailing the process from inception to complete system formation. The components involved in this implementation include the JSN-SR04T Ultrasonic sensor, ESP32 microcontroller, 16 x 2 LCD, LM2596 step-down converter, power supply, servo motor, water tap, measuring tank, and storage tank.

This display features a measuring tank with dimensions of 15 x 15 x 40 cm, designed to serve as a container for measuring used cooking oil. Additionally, beneath the measuring tank is a storage tank that stores the oil measured by volume. The bottom view of the measuring tank, which includes two components: a water tap and a servo motor.

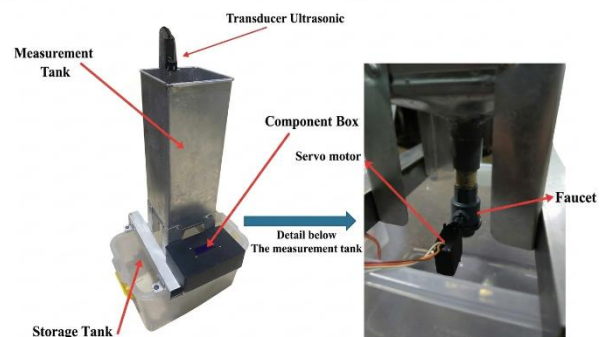


Figure 8. System Implementation

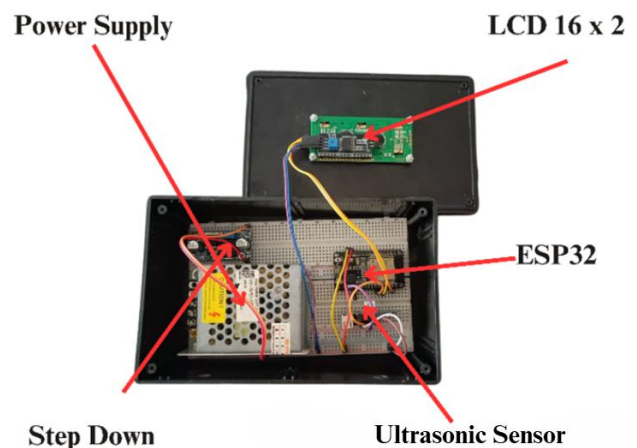


Figure 9. Component Box

UCO Monitoring

Tandon Pengukuran		
Date %	Time	Volume (Liter)
31-07-2024	10:00	2.8
30-07-2024	15:00	2.5
30-07-2024	09:00	4.
21-07-2024	15:00	2.3
11-07-2024	11:00	3.2

Previous Next

Figure 10. Measurement Tank



Figure 11. Storage Tank

Table 1. Ultrasonic Sensor Testing

No.	Test	Sensor distance (cm)	Real distance (cm)	Error	Error (%)
1.	1	38.06	38	0.06	0.15
2.	2	36.08	36	0.08	0.22
3.	3	33.93	34	0.07	0.21
4.	4	32.08	32	0.08	0.25
5.	5	29.98	30	0.02	0.06
6.	6	28.06	28	0.06	0.21
7.	7	26.03	26	0.03	0.11
8.	8	23.99	24	0.01	0.04
9.	9	22.01	22	0.01	0.04
10.	10	20.17	20	0.17	0.85
Error average				0.059	0.214

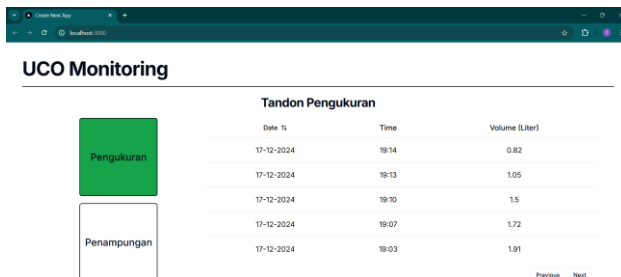


Figure 12. Volume Measurement Results on the Website

Table 2. Comparison of Ultrasonic Sensor with Manual Measurement

No.	Test	Sensor volume (liter)	Real volume (liter)	Error	Error (%)
1.	1	3.61	3.7	0.09	2.43
2.	2	3.28	3.4	0.12	3.52
3.	3	3.03	3.1	0.07	2.25
4.	4	2.71	2.8	0.09	3.21
5.	5	2.41	2.5	0.09	3.6
6.	6	2.12	2.2	0.08	3.63
7.	7	1.85	1.9	0.05	2.63
8.	8	1.52	1.6	0.08	5
9.	9	1.27	1.3	0.03	2.3
10.	10	0.96	1	0.04	4
Error average				0.074	3.257

Figure 9 presents an implementation of the tool component box, which comprises several components that serve distinct functions, like the design system. The website monitoring program runs on

a local network, indicating that the system is accessible only within that network and only when the server is operational. This website is designed to help users monitor the status of the measuring tank and storage tank. The following features are integrated into the website to enhance user experience.

Figure 10 illustrates the website's initial feature: the measurement tank. This feature helps users determine the measurement time, including both the date and the time. Additionally, users can view the quantity of oil recorded in the measurement tank.

Figure 11 illustrates a storage tank. Within this feature, users can view the date and time of oil measurements, as well as the total volume of oil stored in the tank. This functionality facilitates effective tank management, particularly when the oil volume approaches capacity, enabling users to transfer the oil to a larger storage facility.

System implementation encompasses integrating all system components, including hardware and software, in accordance with the design established in the preceding chapter. During this phase, it is essential to test the system to verify that its functionality aligns with the specified requirements.

This system is engineered to quantify the volume of oil entering the measuring tank using an ultrasonic sensor, with the results displayed directly on an LCD and a monitoring website. Upon completion of the measurement and data transmission processes, the tap valve will be opened by a servo motor. After the valve opens, the ultrasonic sensor will take another measurement of the tank. Should this subsequent measurement yield a value of zero or less, the tap valve will automatically close, the LCD will exhibit the result, and the system will transmit the reservoir data to the monitoring website.

During the testing and analysis phase, each hardware component should be tested individually, followed by analysis of the results. The hardware components that are subject to testing include the JSN-SR04T ultrasonic sensor.

The objective of testing the JSN-SR04T Ultrasonic sensor is to assess its capability to measure and detect objects positioned directly in front of it. This evaluation involves connecting the Ultrasonic sensor to a microcontroller and uploading the corresponding program. The testing procedure uses a tank filled with oil, with the Ultrasonic sensor strategically positioned 30 cm above the liquid surface to facilitate accurate measurements to the bottom of the tank.

Table 2 presents the findings from ultrasonic sensor testing compared with actual measurements obtained. The experiments were conducted with a controlled distance variation of 2 cm between each trial, taking into consideration the height of the tank and the ultrasonic sensor's minimum reading capability, which is set at 20 cm. From the table data, the average test error is 0.059 cm. Furthermore, when calculating the error percentage, the average error is 0.214%, as shown in the subsequent calculations.

$$\text{Error average} = \frac{\text{number of errors}}{\text{number of trials}} = \frac{2.14}{10} = 0.214\%$$

Upon conducting the calculations, it was determined that the ultrasonic sensor achieved a success rate of 99.78%. While the sensor's measurements are notably high, several factors can affect its accuracy. These include the sensor's positioning and the presence of fluid ripples during measurement. It is essential for the fluid to remain undisturbed for the ultrasonic sensor to obtain optimal readings. Furthermore, the shape, distance, and size of

the object being measured are critical parameters that can impact the sensor's readings. Additionally, ambient noise can disrupt the operation of the sensor's transceiver and receiver components, thereby affecting the transmission and reception of ultrasonic waves.

This sub-chapter on ultrasonic sensor testing compares ultrasonic sensor measurements, correlating the tank's height with its length and width to determine the tank's volume. Subsequently, these measurement results are compared with the previously quantified fluid volume using a measuring cup.

Figure 12 presents the measurement results obtained from the ultrasonic sensor, which has been integrated with the measurement tank's area to achieve the desired outcomes. These results were derived from periodic oil additions, starting at 1 liter and culminating at 3.7 liters. Subsequently, these measurements were compared with the area calculations, along with the ultrasonic sensor's oil height measurements. The results of this measurement can be accessed via a website or displayed on an LCD, which is also used to present the measurement outcomes.

The results from the experiment indicate that the ultrasonic sensor exhibited an average error of 3.257% in measuring fluid volume. Consequently, the ultrasonic sensor achieves a success rate of 96.74% in this application. Several factors contribute to the variability in ultrasonic sensor measurements, including fluid ripples during measurement, the dimensions of the measurement tank, and sensor reading stability. Additionally, the tank's non-uniform shape may lead to inaccuracies in its volume measurements.

Based on Table 3, which presents testing of the servo motor controlling the water valve. The results show that both fluid types, after measurement, returned the correct results as before the measurement. The results indicate that fluid from the measurement tank flows into the storage tank over varying durations, depending on the volume measured in the measurement tank. A smaller measured volume results in a shorter discharge time, and vice versa. Another factor influencing the fluid transfer time is the fluid's viscosity. As shown in the table, the flow of oil is approximately twice as slow as the flow of water into the storage tank.

Table 3. Servo Motor Performance Testing

No.	Fluid type	Fluid volume before measurement	Fluid volume after measurement	Delay (s)
1.	Water 1	2000 ml	2000 ml	10.23
2.	Water 2	1000 ml	1000 ml	6.21
3.	Water 3	800 ml	800 ml	5.38
4.	Water 4	600 ml	600 ml	4.45
5.	Water 5	400 ml	400 ml	2.96
6.	Oil 1	2000 ml	2000 ml	21.58
7.	Oil 2	1000 ml	1000 ml	13.93
8.	Oil 3	800 ml	800 ml	11.41
9.	Oil 4	600 ml	600 ml	8.41
10.	Oil 5	400 ml	400 ml	6.45

CONCLUSIONS

Based on the research and testing conducted on the Non-Contact Used Cooking Oil (UCO) Volume Measuring Tool within an Internet of Things-based tank, the following conclusions have been drawn. The system can measure the oil level using the JSN-SR04T Ultrasonic sensor in a non-contact manner, achieving 99.78% sensor accuracy. The system effectively measures the volume of oil within the measurement tank by leveraging the JSN-SR04T Ultrasonic sensor, achieving a sensor reading accuracy of 96.74% in conjunction with the tank's area. The system is designed to display the results of the oil measurements taken from the measurement tank, as well as the total oil volume in the storage tank, utilizing a 16 x 2 LCD. The system facilitates the real-time display of the time, including the day, date, and hour of the oil measurement, alongside the oil volume, through the assistance of a dedicated website.

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AUTHOR(S) BIOGRAPHY



Zulafrilian Koto

He received a bachelor's degree in computer engineering from the Faculty of Information Technology, Andalas University.



Arrya Anandika

He received a bachelor's degree (S.Kom) in Computer Engineering from Universitas Andalas, Indonesia, in 2018, and a master's degree (M.T) in Electrical Engineering from Universitas Andalas, Indonesia, in 2021. He is currently a doctoral student in the Graduate School of Science and Engineering, Ibaraki University, Japan. His research interests include Human-Computer Interaction (HCI), Internet of Things (IoT), millimeter-wave radar systems, biomedical signals, and machine learning.



Yuta Sato

He received the B.E. degree in Information Technology and Media Design from the Nippon Institute of Technology (NIT), Miyashiro, Japan, in 2022, and the M.E. degree in Computer and Information Sciences from Ibaraki University, Hitachi, Japan, in 2024. He is currently a Ph.D. student at the Graduate School of Science and Engineering at Ibaraki University. His research interests include Integrated Sensing and Communications (ISAC), millimeter-wave radar systems, UAV systems for inspecting structures, and robot systems for rehabilitation.



Pramawahyudi

He is a lecturer in the Undergraduate Program in Computer Engineering at the Department of Computer Engineering, Faculty of Information Technology, Universitas Andalas. He completed his Diploma III (A.Md) in Informatics Management at Putra Indonesia University, “YPTK” Padang, in 2005, and his bachelor's degree (S.Kom) at STMIK Indonesia Padang (Metamedia University) in 2014. He earned his master's degree (M.T.) in 2022, specializing in Telecommunications and Multimedia and Electrical Engineering, from the Faculty of Engineering, Andalas University. His fields of expertise include Information Security Systems, Computer Networks, and Computer Science.

**Ronaldo Syahputra**

He received his bachelor's and master's degrees in information systems from Putra Indonesia University (YPTK), Padang. He has been actively teaching since 2016. His passion for education and information technology is reflected in his perseverance in writing books and scientific papers. As a writer, he is known for his prolific and consistent sharing of ideas and knowledge. Outside of academics, He is also active as a systems developer, whose work is also beneficial and useful to the community.