ICIC Express Letters
Volume **16**, Number **7**, July **2022**

ICIC International ©2022 ISSN 1881-803X
pp. **769–777**

LIQUID LEVEL ACCURACY MEASUREMENT USING INTERNET OF THINGS (IOT)-BASED MULTIPLE SENSORS IN INDUSTRIAL MIXING PROCESS

Rumengan Brahms Jimmy and Benfano Soewito

Computer Science Department, BINUS Graduate Program – Master of Computer Science
Bina Nusantara University
Jl. K. H. Syahdan No. 9, Kemanggisan, Palmerah, Jakarta 11480, Indonesia
jimmy.rumengan@binus.ac.id; bsoewito@binus.edu

Received January 2021; accepted April 2021

Abstract. *Industries which perform the mixing process of liquids in production process urgently need automated machine technology and accuracy in calculating the liquid level for determining the proportion of liquids that will be mixed with other liquids to produce quality and high-selling end products. Previous research has used one sensor as a height measurement tool or automated machine technology but it cannot be accessed in real time. Human labors do not have an accurate calculation of precision level, causing failure and lowering product quality. This system is designed using two sensors, an Ultrasonic sensor and a Sharp IR sensor. A micro-controller is connected to the Android app so that it can be accessed in real time and a computational process can be done for measuring the accurate liquid level according to the proportion of the liquid and activating an automated pump engine. The results of this research indicate that the method used is much better than those of previous studies.*
Keywords: Sensor, IoT, Liquid level, NodeMCU, Error rate

1. **Introduction.** In industries that have a production system, there are many stages of final product processing. Generally, industries which use liquids as raw materials perform mixing process, in which several raw materials are mixed into one product that has high-selling value. In the production process, determining the proportion of the liquids to produce a quality product is very important [1]. Sophisticated machines have widely been used in industries to achieve a good automation system. The advantages of using an automation system are reduced production costs, shorter production time, and improved product quality [2]. However, in using an automation system, especially pump automation, many industries still use humans to measure liquid level in tanks. Many errors occur because humans are unable to provide a consistent and accurate level of precision. Frequent human errors in calculations result in failure, decreased quality, and failed products. Petrochemical industry and beverage industry have critical parameters in the process of mixing raw materials, especially liquid materials. The critical parameters include the level of liquid in the mixing vessel, temperature, material humidity, and container pressure. In this study, the critical parameter discussed is liquid level. The system is used to regulate the liquid material mixing system with three liquid containers. Each liquid has a volume that is regulated utilizing a reading sensor. In this study, the liquid level was divided into three height categories, namely low (0-5 cm), medium (5-15 cm), and optimal (25 cm). When the three liquids approach a level below 5 cm, the system will display a "low level" warning and when they approach the 25 cm level, the system will display a "maximum height" warning. The low height rating is intended to maintain the stability of the liquid level between 5-25 cm so that the mixing process of the liquid

DOI: 10.24507/icicel.16.07.769

materials does not interfere with the mixing production results in the form of a quality final product under the specified mixing composition. This liquid mixing system uses two sensors, namely an Ultrasonic sensor and an infrared (IR) Sharp sensor. The sensor reading the liquid level and the sensor reading distance are indicators of the liquid level accuracy in each container. If one of the sensors indicates a measurement deviation, then the application system will use the closest average value from the two sensors compared to the actual measuring distance. Using this average value, our IoT mixing system will reduce the liquid waste for better production efficiency.

2. **Theories and Related Works.** Internet of Things (IoT) is a concept that has the goal of expanding the benefits of connecting to an Internet connection continuously. In this context, the research and development challenges of creating a smart world are enormous, a world where real, digital and virtual things come together to create a smart environment that makes energy, transportation, cities, and many other areas smarter [3]. The prototype is the first, step in building a Internet of Things (IoT) product [4]. An IoT prototype consists of interface, hardware devices including sensors, actuators and processors, backend software and connectivity. IoT microcontroller unit (MCU) or development board is employed for prototyping. IoT MCU unit or devboard contains low-power processors which support multi programming environments and should collect data from the sensors using the firmware and processed data to a local or cloud server. NodeMCU is an open source and LUA programming language-based firmware developed for ESP8266 Wi-Fi chip. Espruino, Mongoose OS, software development kit (SDK) provided by Espressif, ESP8266 add-on for Arduino are some of development platforms that will program the ESP8266. ESP8266 could also be wont to either host the appliance or to dump all Wi-Fi networking functions from another application processor through its self-contained Wi-Fi networking solution. Cloud computing and IoT increase the efficiency of everyday tasks and both have a complementary relationship [5]. More specifically, IoT is related to wireless telecommunications. The main goal of the interaction and cooperation between things and objects sent through the wireless networks is to meet the target set as a combined entity [6]. Additionally, both technologies develop rapidly. IoT generates many data while cloud computing provides how for this data to travel as shown in Figure 1.

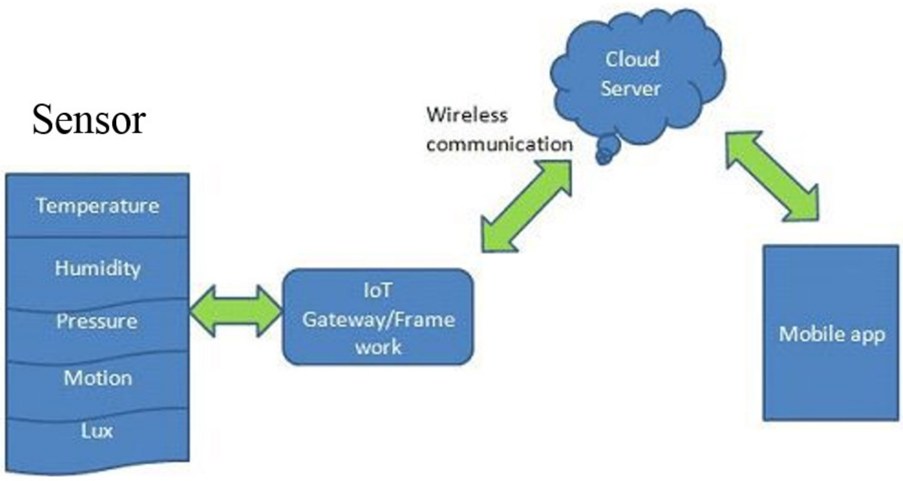


Figure 1. Internet of Things architecture

The IoT system employed in this study uses two sensors, HC-SR04 Ultrasonic sensor (Ultrasonic wave) and GP2Y Sharp IR sensor (infrared wave). The Ultrasonic sensor is a sensor applied to NodeMCU ESP 8266 to detect distance. The HC-SR04 sensor has 2 main components, namely the Ultrasonic transmitter and the Ultrasonic receiver. The transmitter emits Ultrasonic waves with a frequency of 40 kHz and the receiver captures the results of the reflected Ultrasonic waves hitting an object. The travel time of the Ultrasonic wave is 1/2 t and the time of the reflection is 1/2 t [7]. Ultrasonic sensor HC-SR04 is used in this study because it has stable performance, accurate distance measurement with 0.3 cm accuracy, maximum measurement which can reach 4 meters with a minimum distance of 2 cm, and the ability to operate at TTL voltage levels. The second sensor used is GP2Y Sharp IR sensor. GP2Y Sharp IR sensor is a sensor that calculates the distance of an object by utilizing the principle of infrared light reflection. The GP2Y Sharp IR sensor output is an analog voltage. The voltage generated from this sensor has a value inversely proportional to the distance the sensor can read [8]. The GP2Y0A41SKOF Sharp IR sensor measures the detection distance of 4-30 cm. The GP2Y0A41SKOF Sharp IR sensor has parts, namely the transmitter/emitter and receiver. The part of the transmitter which has a light emitting diode (LED) will emit a modulated infrared signal and the receiver will catch the infrared reflection, where the receiver has a focusing lens and a position-sensitive detector. While previous studies measured the liquid level, this study focuses on the suitability of the IR sensor to detect the water level in the tank and the active measurement of the non-turbulent water surface where the IR sensor is inexpensive and can provide reliable water level measurements so that the results provide a good agreement between the expected level and the real data obtained during the experiment. The Internet of Things (IoT) system can also have complete transparency of the water level of the smartphone [9]. [10] looks at the problem of water that is wasted a lot from storage places due to the absence of a liquid level control system that can be accessed in real time because it still uses a manual system. Therefore, a water level measurement system using an Ultrasonic sensor which is applied to the Arduino and gsm module delivers short message service (SMS) about the water level to the user periodically and also the user can control the motor pump automatically [11]. Research entitled *Design of Volume Monitoring and Water Filling System Using Ultrasonic Sensor Based on AVR ATMega8 Micro-Controller* [12] consisted of a keypad, LCD (liquid crystal display), ATMega8535 microcontroller, Ultrasonic sensor, driver, buzzer and LED. The monitoring system that has been developed is good enough, but it needs to be developed into a better monitoring system in terms of flexibility. In 2017, there was a study [13] on how to control the volume of water in hydroponic plants automatically. This research has something in common in that the system detects the water level which is then processed with Arduino Uno. Meanwhile, the difference is that the water level was divided into three levels: low, medium, and high. The pump used is the filling and suction pump [14]. The position of the buoy that moves at the time of filling and emptying the water in Toren causes the infrared sensor to be unable to detect the distance of the buoy appropriately, obstructing the work of the water pump which should have been turned on or have died at his level. In this study, a real-time water level control and monitoring system was built using several sensors and an Android. Based on the above studies, it was found that in measuring the level of liquid in the tank, Ultrasonic sensors and IR sensors can be applied to the NodeMCU and a pump engine automation system could be made. Liquid level control is a typical representation of process control and has been widely used in iron and steel, chemical, petroleum and other industries [15]. The control quality directly affects the standard of products and safety of apparatus. However, the liquid level system of cistern could even be an oversized lag, time-varying and nonlinear complex system and is incredibly difficult to manage. Now, the liquid level control has been an energetic area within the tactic control over last decades and various different approaches are devised. In this exercise, the system is to model, calibrate, and control one & twin or two tank level system. A prototype tool for measuring sea level height based on the ATMega328 microcontroller was built, where the measurement system is based on the working principle of buoys and infrared sensors so that it can measure the sea level directly [16]. This instrument records measurement data into data storage media. The research stages consist of designing, manufacturing, and testing the tools. This tool is designed to measure sea level with a distance of 15-110 cm from the sensor used.

3. **Methodology.** Designing a system block diagram according to Figure 2 is the initial stage of the system design. All sensors and devices connected to the NodeMCU ESP8266 sending data record to the database and all data can be viewed using Arduino smartphone and a web-based application [17].

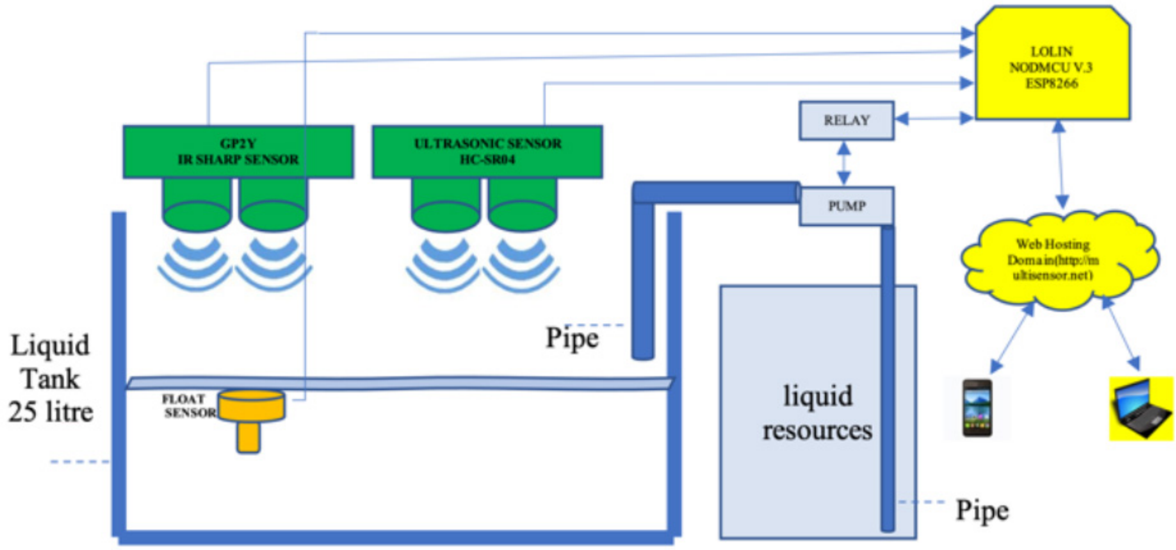


FIGURE 2. System block diagram

At this stage, data collection activities for the height measurement of the three types of search were carried out. The fluids used were water, vegetable oil and SAE 40 oil, where these three fluids have different viscosity levels [15]. An experiment was carried out with the Ultrasonic sensor HC-SR04 on liquid. The Ultrasonic sensor was mounted on an acrylic backing board and the distance between the Ultrasonic sensor and the liquid surface was carried out by varying the surface height measurements between 0-5 cm, 5-15 cm and 25 cm. The liquid level measurement by the sensor was compared with a manual measuring tool using a ruler. This measurement test was carried out at a height of 0-5 cm, 5-15 cm (medium) and 15-30 cm (high). From the results of this measurement, the average value was calculated according to the three types of liquids tested and the calculated precision of the Ultrasonic sensor measurements and the Sharp IR sensor. The results can be used as a reference for the actual measurement. In this process, it can be seen that when the height is 0-5 cm, the system will give a warning about the limit of the liquid level, which is less than 5 cm and when the liquid level reaches 25 cm, the system will give a warning regarding the optimum liquid level.

This proposed IoT system produces liquid level notification and exact output of the average value. Furthermore, all tests were carried out on software monitoring systems according to the application architecture shown in Figure 3.

Figure 3 also explains how the IoT application system infrastructure works where NodeMCU ESP8266 sends altitude information data through Cloud Hosting Multisensor.net and the information about liquid level and warning notification is displayed through the PHP programming language interface from the stored MySQL database, then it uses the REST API as middleware [19] so that it can be viewed both on mobile devices and web-based application.

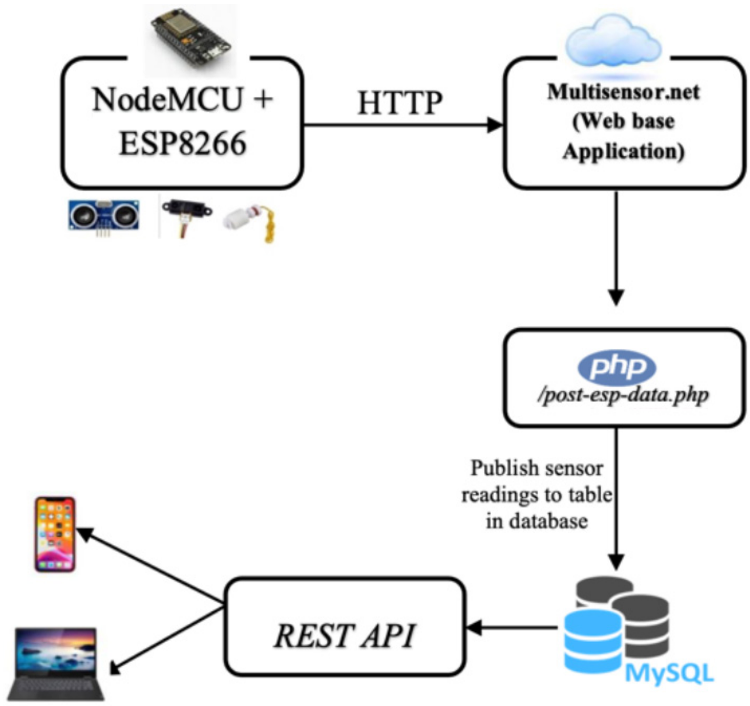


Figure 3. Application infrastructure

4. **Data Testing & Evaluation Analysis.** 2 sensors were used to measure the level of the liquid and compare the results by obtaining the average liquid level from each sensor including the average sensor reading distance to the liquid surface. To evaluate the system performance, this research used standard deviation and error rate calculation [20].

Table 1. Average liquid level 0-5 cm

Num	Liquid type	Viscosity (mPa-s)	Actual height (cm)	Average height of Ultrasonic sensor (x)	$(x - x(mean))^2$	Average height of Sharp IR sensor (y)	$(y - y(mean))^2$
1	Water	1.00	3.7	3.9	0.0169	3.8	0.0289
2	Lubricant SAE 40	319	3.7	3.7	0.0049	3.5	0.0169
3	Vegetable Oil	65	3.7	3.7	0.0049	3.6	0.0009
Combined value ($n = 90$ test samples)				Average 3.8	Total: 0.0267	Average 3.63	Total: 0.0467

From Table 1, the Ultrasonic sensor variant value x (S_x^2) and Sharp IR sensor y (S_y^2) can be done through the following calculations:

$$S_x^2 = \frac{\sqrt{\sum(x - x(mean))^2}}{n-1} = \frac{\sqrt{0.0267^2}}{89} = \frac{\sqrt{0.00071289}}{89} = \frac{0.0267}{89} = \mathbf{0.0003}$$

$$S_y^2 = \frac{\sqrt{\sum(y - y(mean))^2}}{n-1} = \frac{\sqrt{0.0467^2}}{89} = \frac{\sqrt{0.00218089}}{89} = \frac{0.0467}{89} = \mathbf{0.000525}$$

Thus, the standard deviation value of the Ultrasonic sensor x $(SD_x) = \sqrt{S_x^2} = \sqrt{0.0003}$ $= 0.01732 = 1.73\%$ and standard deviation value of Sharp IR sensor y $(SD_y) = \sqrt{S_y^2} = \sqrt{0.000525} = 0.02291 = 2.29\%$. Then for the Ultrasonic sensor standard error x $(SE_x) = \sqrt{(S_x^2/n)} = \sqrt{(0.0003/90)} = 0.0018257 = 0.18\%$ and standard error of Sharp IR sensor y $(SE_y) = \sqrt{(S_y^2/n)} = \sqrt{(0.000525/90)} = \sqrt{0.000005833} = 0.0024152 = 0.24\%$.

TABLE 2. Average liquid level 5-15 cm

Num	Liquid type	Viscosity (mPa-s)	Actual height (cm)	Average height of Ultrasonic sensor (x)	$(x - x(mean))^2$	Average height of Sharp IR sensor (y)	$(y - y(mean))^2$
1	Water	1.00	14.9	14.9	0.0049	15.0	0.0009
2	Lubricant SAE 40	319	14.9	14.9	0.0049	15.6	0.3249
3	Vegetable Oil	65	14.9	14.7	0.0169	14.5	0.2809
Combined value ($n = 90$ test samples)				Average 14.83	Total: 0.1149	Average 15.03	Total: 0.6067

From Table 2, the Ultrasonic sensor variant value x (S_x^2) and Sharp IR sensor y (S_y^2) can be done through the following calculations:

$$S_x^2 = \frac{\sqrt{\sum(x - x(mean))^2}}{n-1} = \frac{\sqrt{0.1149^2}}{89} = \frac{\sqrt{0.0132}}{89} = \frac{0.1149}{89} = \mathbf{0.00129}$$

$$S_y^2 = \frac{\sqrt{\sum(y - y(mean))^2}}{n-1} = \frac{\sqrt{0.6067^2}}{89} = \frac{\sqrt{0.3681}}{89} = \frac{0.6067}{89} = \mathbf{0.00682}$$

Thus, the standard deviation value of the Ultrasonic sensor x $(SD_x) = \sqrt{S_x^2} = \sqrt{0.00129}$ $= 0.0359 = 3.59\%$ and standard deviation value of Sharp IR sensor y $(SD_y) = \sqrt{S_y^2} = \sqrt{0.00682} = 0.0826 = 8.26\%$. Then, for the Ultrasonic sensor standard error x $(SE_x) = \sqrt{(S_x^2/n)} = \sqrt{(0.00129/90)} = 0.0038 = 0.38\%$ and standard error of Sharp IR sensor y $(SE_y) = \sqrt{\left(S_y^2/n\right)} = \sqrt{(0.00682/90)} = 0.0087 = 0.87\%$.

TABLE 3. Average liquid height level 25 cm

Num	Liquid type	Viscosity (mPa-s)	Actual height (cm)	Average height of Ultrasonic sensor (x)	$(x - x(mean))^2$	Average height of Sharp IR sensor (y)	$(y - y(mean))^2$
1	Water	1.00	25	25.0	0.0049	25.08	177.69
2	Lubricant SAE 40	319	25	25.1	0.0009	5.1 (error)	44.22
3	Vegetable Oil	65	25	25.1	0.0009	5.07 (error)	44.62
Combined value ($n = 90$ test samples)				Average 25.07	Total: 0.0067	Average 11.75	Total: 266.53

From Table 3, the Ultrasonic sensor variant value x (S_x^2) and Sharp IR sensor y (S_y^2) can be done through the following calculations:

$$S_x^2 = \frac{\sqrt{\sum(x - x(mean))^2}}{n-1} = \frac{\sqrt{0.0067^2}}{89} = \frac{0.0067}{89} = \mathbf{0.0000753}$$

$$S_y^2 = \frac{\sqrt{\sum(y - y(mean))^2}}{n-1} = \frac{\sqrt{266.53^2}}{89} = \frac{266.53}{89} = \mathbf{2.995}$$

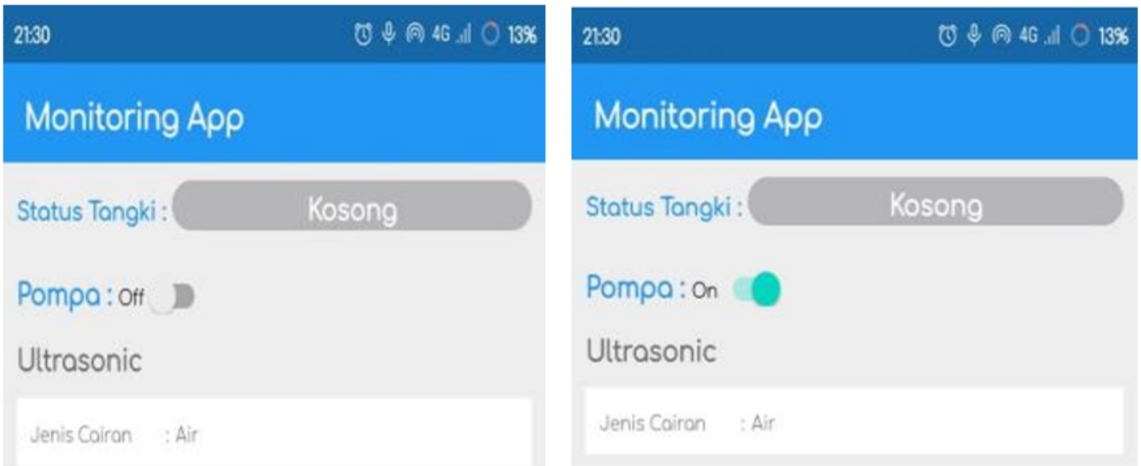
Thus, the standard deviation value of the Ultrasonic sensor x $(SD_x) = \sqrt{S_x^2} = \sqrt{0.0000753} = 0.0087 = 0.87\%$ and standard deviation value of Sharp IR sensor y $(SD_y) = \sqrt{S_y^2} = \sqrt{2.995} = 1.73 =$ **173%**. Then for the Ultrasonic sensor standard error x $(SE_x) = \sqrt{(S_x^2/n)} = \sqrt{(0.0000753/90)} = 0.000915 = 0.092\%$ and standard error of Sharp IR sensor y $(SE_y) = \sqrt{(S_y^2/n)} = \sqrt{(2.995/90)} = \sqrt{0.033} = 0.182 = \mathbf{18.2\%}$. Finally, in this test the Sharp IR sensor is not recommended in measuring the liquid height of 25 cm because the standard deviation reaches 173% and the standard error reaches 18.2%.

Liquid Level Warning Detection. Below are the results of the Ultrasonic sensor-based pump test detected in the test equipment. The experiment was carried out at a height between 0 cm and 5 cm.

TABLE 4. Liquid level 0-5 cm warning information

Num	Status	Actual level (cm)	Reading measurement level (cm)	Delay latency (ms)
1	WARNING!! Liquid Level Below 5 CM!!	5	5	1000
2	WARNING!! Liquid Level Below 5 CM!!	4.9	4.9	1000
3	WARNING!! Liquid Level Below 5 CM!!	4.5	4.5	1000
4	WARNING!! Liquid Level Below 5 CM!!	4	4	1000

Warnings or notifications of liquid levels below 5 cm will be shown on the Android application by NodeMCU with a display like Figure 4 below, and the user must press the On button on the Android App.



(a) (b)

FIGURE 4. (a) Pump status is Off; (b) Pump status is On.

Table 5 presents the results of the Ultrasonic sensor-based pump trial, where the experiment was carried out at a liquid level between 25 cm and 30 cm.

TABLE 5. Liquid level <= 25 cm warning information

Num	Status	Actual level (cm)	Reading measurement level (cm)
1	WARNING!! Liquid Level Above 25 CM!!	25	25
2	WARNING!! Liquid Level Above 25 CM!!	25.5	25.5
3	WARNING!! Liquid Level Above 25 CM!!	26	26
4	WARNING!! Liquid Level Above 25 CM!!	26.8	26.8

A warning or notification of a liquid level above 25 cm will be shown on the Android application by NodeMCU with a display like Figure 4(b) and the user must press the Off button on the Android App to turn off the pump so that the liquid is not wasted. The display on the Android application has shown testing of the pump automation system based on Ultrasonic sensors has been successfully carried out, showing that it can work at a predetermined height as a lower limit between 0-5 cm and it will give a warning by NodeMCU to the Android App that the liquid level is less than 5 cm and the pump must be turned on via the pump On button on the Android App. If the Ultrasonic sensor detects a liquid level above 25 cm, NodeMCU gives a warning that the liquid level has reached 25 cm and the pump must be stopped via the pump Off button on the Android App.

5. **Conclusion.** An IoT device model connected to an Ultrasonic sensor and an infrared sensor is able to display accurate water and oil level data at an altitude of 0-25 cm. However, the Sharp IR sensor is inaccurate, showing 25 cm height data for oil and vegetable oil with an average error rate of 19.86%-19.93%. The IoT system works very well and can give automatic warning information if the height is close to the minimum value $<= 5$ cm and the maximum height value is 25 cm, which instructs the pump to On/Off, refilling the liquid with a latency delay value of 1000 ms.

Acknowledgments. The author would like to thank Benfano Soewito, M.Sc., Ph.D. who has contributed in the research and helps the author complete this journal article. I also thank my colleagues in the Informatics Engineering Master's Program, and especially my wife and children who are always helpful.

REFERENCES

[1] A. W. Nienow, M. F. Edwards and N. Harnby, *Mixing in the Process Industries*, Butterworth-Heinemann, 1997.

[2] M. Sreejeth and S. Chouhan, PLC based automated liquid mixing and bottle filling system, *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, pp.1-5, 2016.

[3] O. Vermesan and P. Friess, *Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*, River Publishers, Denmark, 2013.

[4] Y. S. Parihar, Internet of Things and nodemcu: A review of use of Nodemcu ESP8266 in IoT products, *Journal of Emerging Technologies and Innovative Research (JETIR)*, vol.6, no.6, pp.1085-1088, 2019.

[5] K. Chamandeep, The cloud computing and Internet of Things (IoT), *IJSRSET*, pp.1085-1088, 2020.

[6] C. Stergiou, K. E. Psannis, B.-G. Kim and B. Gupta, Secure integration of IoT and cloud computing, *Future Generation Computer Systems*, vol.78, no.3, pp.964-975, 2018.

[7] I. M. Métrologie, Water level detection system based on Ultrasonic sensors HC-SR04 and ESP8266-12 modules with telegram and buzzer communication media, *IIETA*, vol.18, no.3, pp.305-309, 2019.

[8] S. Mukhopadhyay and I. R. Karas, Monitoring of rainfall level ombrometer observatory (OBS) type using Android Sharp GP2Y0A41SK0F sensor, *International Journal of Advanced Computer Science and Applications (IJACSA)*, 2019.

[9] P. V. Rao and S. B. Chaudhury, Smart active liquid level measurement using infrared sensors suitable as consumer products, *IJRETS*, pp.2454-1915, 2017.

[10] Mali, Shinde and Kale, *Live Water Level Indicator with SMS and Voice Call Alerts Using Arduino and Ultrasonik Sensor. 9*, 2019.

[11] W. Widiasih and H. Murnawan, Design and build a water level control unit in a reservoir, *HEURISTIC: Journal of Industrial Engineering*, vol.13, no.2, 2016.

[12] A. Permana, D. Triyanto and T. Rismawan, Design and build a volume monitoring system and water filling using ultrasonic sensors based on the ATMega8 AVR microcontroller, *Coding Computer Journal and Applications*, vol.3, no.2, pp.76-87, 2013.

[13] A. Jalil, Water level detection control system in hydroponic growing media based on Arduino, *JURNAL IT*, vol.8, no.2, pp.97-101, 2017.

[14] K. Prawiroredjo and I. M. Susantio, *Automatic Water Level Regulator*, 2010.

[15] ElertGlenn (1998-2020), *The Physics Hypertextbook*, https://physics.info/viscosity/, https://www.nodemcu.com/index_en.html.
[16] S. Sharma, M. Arora and K. Kaushik, Analysis of liquid level control of coupled tank system by PI, PD, PID controller, *IJSTR*, 2015.
[17] M. I. Jumarang and A. Muid, Making a prototype of a sea level measuring tool using an infrared sensor based on an ATMega328, *POSITRON*, pp.64-70, 2014.
[18] D. A. Aziz, Webserver based smart monitoring system using ESP8266 Node MCU module, *International Journal of Scientific and Engineering Research (IJSER)*, vol.9, no.6, pp.801-807, 2018.
[19] N. Dipsis and K. Stathis, A RESTful middleware for AI controlled sensors, actuators and smart devices, *Journal of Ambient Intelligence and Humanized Computing*, pp.2963-2986, DOI: 10.1007/s12652-019-01439-3, 2019.
[20] D. K. Lee, J. In and S. Lee, Standard deviation and standard error of the mean, *Korean Journal of Anesthesiology*, vol.68, no.3, 2015.