Design of Monitoring System for Infused Liquid Volume Based Wireless Communication

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***Abstract*—Technological developments are now growing faster, one of which is IoT technology that can facilitate human activities. In the conditions of the Covid-19 pandemic, an innovation is needed that can take advantage of technological developments to reduce physical contact in order to slow the spread of the corona virus. This research aims to create a monitoring system for infusion volume in patients who are monitored through the website. The detected sine volume will be displayed in units of weight, namely grams. The data obtained from the sensor nodes will be sent to the MySQL database via wireless communication and displayed on the website. The error result obtained from the infusion weight test is 0.9% which indicates the system can detect the weight well. Data from sensor nodes sent to the website has an error of 0.35%. When the infusion rate is less than 80 grams, a notification will appear and the system is 100% able to display a notification when it reaches that state.**

Keywords—IoT, covid-19, infusion.

I. Introduction

Covid-19 is a disease caused by a viral infection that attacks the respiratory organs in humans. Corona virus transmission can occur between humans through sprinkling of phlegm or saliva of COVID-19 sufferers when coughing or sneezing. This virus is also believed to be able to float in the air and survive for some time, especially in closed spaces[1]~[4]. Transmission of this virus can be through droplets and direct contact with infected people. In handling COVID- 19, many health workers have died in carrying out their duties due to too frequent direct contact with patients infected with COVID-19. Therefore, during a pandemic like this, we must tighten the implementation of health protocols to avoid the transmission of the COVID-19 virus, such as wearing masks, washing hands, and keeping a distance according to government regulations.

In handling a viral infection or other health problems, an infusion is needed to provide medicinal fluids and vitamins for the patient's healing process. Infusion is a method of administering fluids and drugs directly through a vein. Fluids given by infusion can serve as maintenance fluids or resuscitation fluids [5]~[8]. In the health sector, weight data is also needed for patient data. Nowadays, there are many digital scales that use the HX711 load cell sensor. However, this load cell sensor is not only used to detect a person's weight, but in this research it is used to detect the weight of the infusion.

In responding to this pandemic condition, a system was created to monitor the volume of infusion fluids that can be monitored through the website to reduce direct contact of nurses with patients. By reducing direct contact with patients, it can reduce the transmission of the Covid-19 virus. The system is made using the concept of IoT (Internet of Things) which is integrated with a 5kg capacity HX711 load cell sensor to detect infusion weight. The Internet of Things, or commonly referred to as the Internet of Things, is an idea in which all objects in the real world can communicate with each other as part of an integrated system that uses the Internet as a connection. Basically, IoT devices are composed of sensors as data collection media, Internet connections as communication media, and servers as sensors to receive and analyze information collectors [9]~[12]. The data that has been obtained is then sent to the server using a Wi-Fi connection from ESP32 with the HTTP Post method. The data that has been received by the server can later be accessed and displayed through the website. The system created in the future can be applied to more than two nodes and the treatment of patients who are treated at home respectively. This system can be used and applied in urgent situations such as the current covid-19 pandemic.

II. Related Work

In the paper entitled "Infusion Monitoring Tool Set for Inpatients Based on the ATmega 8535 Microcontroller" made a tool to detect droplets in the Infusion chamber. The droplets are detected by light sensors, namely infrared LEDs and photodiodes. The voltage signal from the sensor is regulated by the LM339 comparator IC. The ATmega 8535 microcontroller is used as the comparator's I/O data processor, so the information from the monitoring parameters can be displayed on the LED and LCD and the buzzer. The output voltage when the infrared sensor detects a drop is 1.02 V, and the output voltage when no drop is detected is 180 mV. The parameters that can be detected from the tool include the number of drops per minute (the maximum number of drops detected per minute is 255 drops), a warning if drops are not detected within 10 seconds, and a warning when the infusion will run out (± 50 Ml). The sound from the buzzer still sounds clear, and it is harmless to the nurse's hearing according to the noise level threshold, even when the nurse's room is crowded[13].

In the paper entitled "Monitoring of Infusion Fluids Based on Conditions and Rates of Infusion Indicators Using a Wi-Fi Network" discusses the design of a monitoring system that can monitor the condition of intravenous fluids in real time using a PC or smartphone. This system works to regulate the infusion drip per minute and notify the condition of the infusion fluid that will run out. The results of the test showed that the infusion drip setting was inaccurate, there were differences that varied in each test, while the test for the condition of the infusion fluid worked properly, this was evidenced by the alarm on the PC and smartphone that always sounded when the infusion fluid was about to run out [14].

In the paper entitled "Design of Infusion Fluid Remaining Monitoring System and Infusion Flow Control Using a Wireless Network" which makes a detection and control device for intravenous fluids using sensors ultrasonic that can be accessed over a wireless network. This tool uses the HCSR04 ultrasonic sensor to detect the height of the infusion liquid and convert it to the liquid volume on the Arduino Uno. If the liquid reaches the minimum volume, the servo motor will move to stop the flow in the infusion tube. The communication between the ward and the intensive care unit uses Xbee S2. The transmitter module located on the Arduino sends the data to the Uartsbee module receiver on the computer in the monitoring room. The patient's remaining infusion information is displayed on the GUI (graphical user interface) of the intensive care unit. Display GUI (graphical user interface) designed using Microsoft Visual Basic 6.0 [15].

In a paper entitled "IoT based wristband for Intravenous infusion level monitoring in healthcare," research is conducted on a patient infusion fluid detection system using a weight sensor that utilizes IoT technology. Generally, if a patient is under saline infusion, there arises a need to monitor the patient continuously by an observer/nurse in the hospitals. In several cases, it becomes unfortunate when the doctor, nurse or care taker forgets to alter the bottle at appropriate times due to their hectic work schedules. It results in flow back of blood into the IV tube putting patient's life under risk. The proposed model prevents this crucial problem by innovating an IoT interfaced automatic alerting and intimating wristband device by using a weight sensor to maintain the saline level. It functions as follows: If the saline level/weight drops down than a defined limit, the sensor intimates by changing its output. Also it alerts the observer through a display in wrist band indicating the room number of the patient to avoid any critical situation. The data is sent to nurse and they can start or stop the fluid. It also helps in monitoring fluid condition. The proposed model has salient features like reliability, affordability, reusability and convenience for the usage by doctor/nurse. The same arrangement can be reused again for other bottles. It is advantageous for both doctors and staff nurse specifically in rural hospitals. The system makes easier for nurse/observer to monitor the level of saline bottle remotely[16].

In a paper entitled "Web-based intravenous fluid monitoring" research is conducted on a patient infusion fluid detection system using a weight sensor using a website-based MCU Node. This study aimed to provide a web-based intravenous fluid monitoring using NodeMCU. The sensor consisted of a load cell sensor as a reader for the remaining infusion fluid, an optocoupler sensor as a blood detector, and a photodiode sensor to read the number of drops. In the event of dangerous situations such as an intravenous fluid running out, blood entering the intravenous line or the liquid is not dripping, the tool will give a warning through status LED, buzzer sound, and warning sounds on the web. This system has an error value of 3.12% for mass readings, 6.47% errors for droplet readings and 0% errors for blood detection. This system works by utilizing a Wi-Fi internet network. This system is expected to enable nurses, doctors, and patient's families to monitor a patient's intravenous fluids in real-time conditions[17].

III. Methodology

This research aims to create a monitoring system for the volume of infusion fluids in patients that can be monitored via a website on a computer in the monitoring room. The infusion volume displayed on the website is in grams. This system will give a warning to officers when the infusion volume is less than 80 grams.

In this research, two sensor nodes were created to be monitored. Each sensor node uses a load cell sensor, HX11 module, Arduino nano, and ESP32. The load cell sensor in this system is useful for detecting weight in the form of voltage data which will then be converted to digital data by the HX711 module. The HX11 module not only functions as an ADC (Analog to Digital Converter) but also as an amplifier [18]. The data from the HX11 will be forwarded to the arduino nano to be converted to grams. Infusion weight data in grams will be sent to ESP32 which is then forwarded to data transmission to the database using a Wi-Fi connection by implementing the HTTP Post delivery protocol. ESP32 is a series of low budget and low power systems on a microcontroller chip with integrated Wi-Fi and dual mode Bluetooth [19]~[22]. Between Arduino nano and ESP32 using serial communication. The data stored in the database will then be displayed on the website in real time. The illustration of the entire system created is shown in Fig. 1.

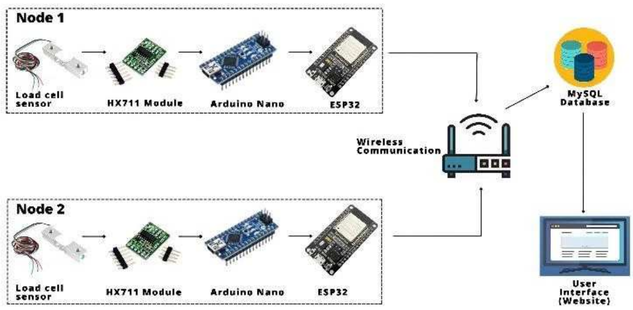

Fig. 1. Illustration of System Implementation

Fig. 1 describes the illustration of the system used and the components used in the system that was created. The system is made up of two nodes, where each node uses the same components. The only difference is in the program that is uploaded on each node.

In this research, the data in the database will be displayed through the website. Weight data in grams will be displayed in percent for easy monitoring. When the infusion volume is at a value of 80 grams, a reminder notification will appear so that the officer checks the patient's infusion directly. To build a system on the hardware side, it is programmed using Arduino IDE which is software that is able to adapt to the Arduino board used and this software is also open source, so it is easy to get it [9]. While on the website side, the HTML, CSS, PHP, and JavaScript programming languages are used to create views and can display data stored in the database.

The implementation design of the system based on the illustration above can be shown in Fig. 2. Fig. 2 describes the placement of the hardware system on the infusion pole used by the patient. Hardware system of the two nodes that have been assembled will be mounted on different sides of the pole. This is to compare the two nodes are placed in different places. The power source used to run the system comes from a rechargeable power bank. The physical form of the system that has been designed can be seen in Fig. 3.

Based on the design and workings of the system described previously, when testing the system, the error value for testing the accuracy of the load cell sender is 5%. If more than 5% it is necessary to check the system. The calculation of the error value in the system is obtained from the calculation of absolute error with the formula as in equation 1.

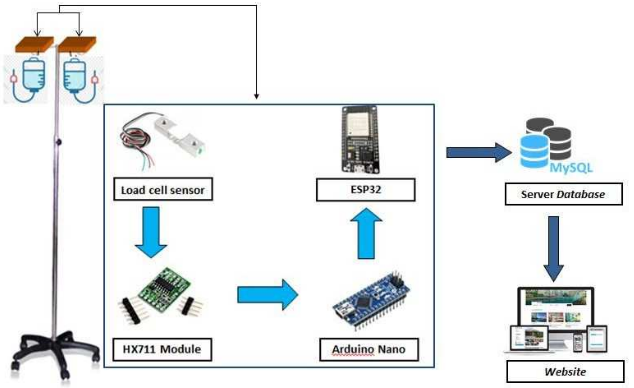

Fig. 2. System Implementation Design

Fig. 3. Physical Shape of Device

When the ESP32 power is connected to the power bank, the system will start working. The system will start detecting the infusion weight when the infusion bag is attached to the load cell sensor. As the volume of infusion fluid decreases, the value displayed on the website will also decrease in real time.

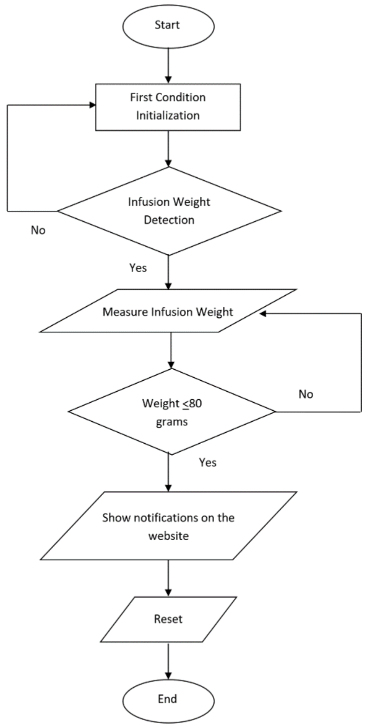

Fig. 4. Flowchart of The Program System.

Based on the design and workings of the system described previously, when testing the system, the error value for testing the accuracy of the load cell sender is 5%. If more than 5% it is necessary to check the system. The calculation of the error value in the system is obtained from the calculation of absolute error with the formula as in equation 1.

$$\%absolute\ error = \frac{standard\ scale\ (g) - load\ cell\ (g)}{standard\ scale\ (g)}\ x\ 100$$

(1)

IV. SIMULATION RESULTS

A. Sensor Reading Accuracy Test

The sensor accuracy test has the aim of analyzing whether the sensors used in the system are running well or not. This test was carried out on the load cell sensors at node 1 and node 2.

1) Load Cell at Node 1: The test is carried out by comparing the results of measuring the infusion weight using a standard scale and a load cell sensor at node 1. There are two sensor accuracy tests, namely by weighing five different objects and weighing the infusion from full to full by recording every 15 gram reduction. The results of the test are more clearly shown by the graph in Fig. 5.

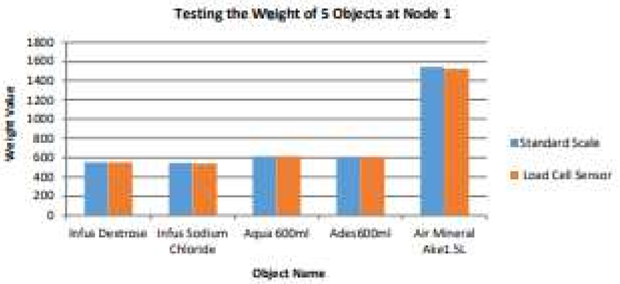

Fig. 5 Graph of Testing the weight of 5 Objects at Node 1.

Based on the test, the blue bar chart shows the results of measuring the weight of the standard scales while the red bar chart shows the results of the load cell sensor measurements. Based on the graph, the infusion weight values obtained from standard scales and load cell sensors have almost the same value.

The second test is to compare the weight of the infusion which is weighed using a standard scale and a load cell sensor for every 15 grams weight reduction. The results of the second test are shown in Fig. 6.

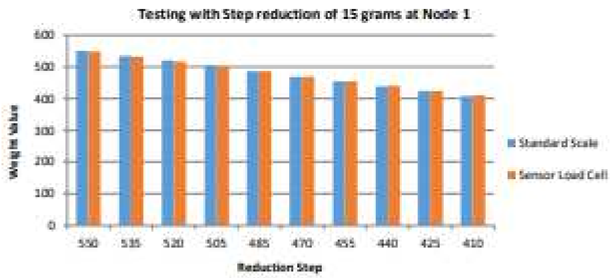

Fig. 6 Graph of the test with a 15 gram reduction step at node 1.

Based on this test, the blue bar chart shows the results of measuring the weight of the standard scales, while the red bar chart shows the results of the load cell sensor measurements. Based on the graph, the infusion weight values obtained from standard scales and load cell sensors have almost the same value. With this, the accuracy of the load cell sensor used is good.

2) Load Cell at Node 2: The load cell sensor test at node 2 is also the same as the test carried out at node 1, namely the test comparing the weight of five different objects and comparing the results of the infusion weight with a 15 gram reduction step. The results of the test comparing the weight of the five objects are shown in Fig. 7.

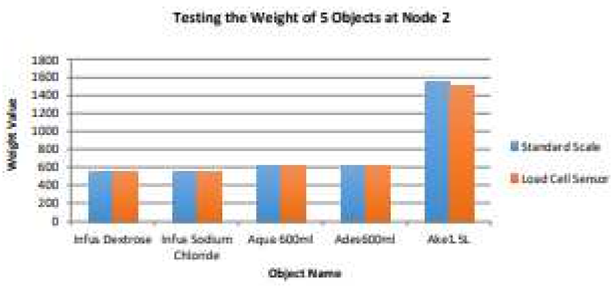

Fig. 7. Graph of Testing the weight of 5 Objects at Node 2.

The next test is to compare the weight of the infusion with a 15 grams reduction step. The results of these tests are shown in Fig. 8.

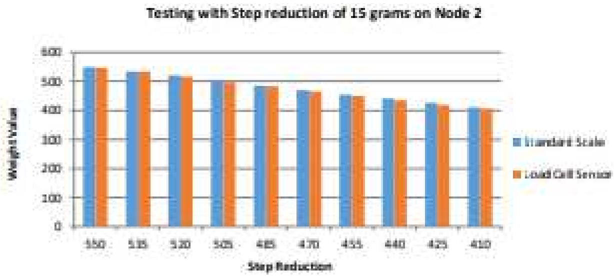

Fig. 8 Graph of the test with a 15 gram reduction step at node 2

Based on the graph, the load cell sensor used in the node 2 circuit functions well and has good accuracy.

B. Testing Data Delivery to Website

In the test of sending data to the website, it is done by comparing the weight value of the infusion that is hung on the load cell sensor that appears on the serial monitor on the Arduino IDE application, the value stored in the database and the value that appears on the website. This test aims to determine the accuracy of data transmission obtained by the sensor so that it can be displayed on the website. The value recorded is each reduction in infusion weight of 20 grams. This test is carried out on node 1 and node 2 with the same steps. Based on the results of the tests that have been carried out, a graph can be made of the weight values displayed on the website from node 1 and node 2 even though the infusion weight used during testing is different. The graphic image is shown in Fig. 9.

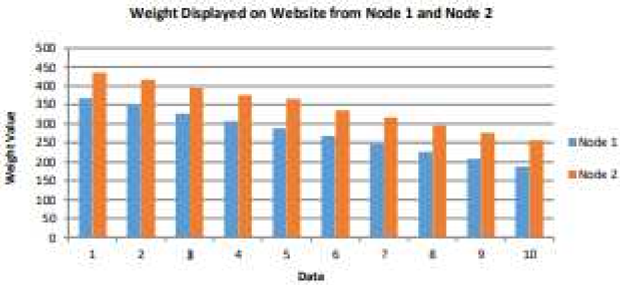

Fig. 9 Graph of the weight values on the website of node 1 and node 2

C. Testing the Apperance of Notifications

In testing the emergence of notifications, it is done by making a condition, namely the infusion weight is less than 80 grams (⩾ 80 grams) at node 1 and node 2 alternately 10 times. The purpose of this test is to find out that the infusion warning is running out in the form of an "alert" notification that is functioning properly.

TABLE I. NOTIFICATION TEST RESULTS

No.	**Weight (gr)**		**Notification**	
	Node 1	***Node 2***	***Node 1***	***Node 2***
1	167.03	79.83	X	V
2	145.35	79.56	X	V
3	122.61	78.98	X	V
4	106.89	79.03	X	V
5	95.31	79.41	X	V
6	79.59	179.31	V	X
7	79.32	156.87	V	X
8	79.9	178.94	V	X

9	79.67	159.52	V	X
10	79.43	179.07	V	X

Based on the results obtained in table I, a notification will appear when the infusion weight has met the specified conditions, which is less than equal to 80 grams. The five-time test on node 1 succeeded in generating notifications when the infusion weight was less than 80 grams, while at node 2, the heavier volume of infusion was hung in order to determine whether the notification was successful or not. The same test that was carried out at node 1 was also carried out at node 2 by setting the infusion at node 2, the weight is lighter than the infusion weight at node 1. The test at node 2 also successfully generated notifications when the infusion weight was less than 80 grams.

D. Testing of Data Delivery to Website

At this stage of testing, the infusion volume value was observed based on the time the data appeared on the serial monitor, database, and website. In this test, it was carried out for 10 times with a vulnerable time between tests of 2 minutes. The observed time is in units of hours, minutes, and seconds. Tests were carried out on node 1 and node 2 with the same conditions. The results of the delay test at node 1 are shown in table II and the results for testing node 2 are shown in table III.

TABLE II. TESTING DELAY ON NODE 1

No.	**Time**			**Delay (second)**	
	Serial Monitor	***Database***	***Website***	***Serial Monitor-Database***	***Database -Website***
1	23:40:24	23:40:27	23:40:29	3	2
2	23:42:17	23:42:18	23:42:22	1	4
3	23:44:31	23:44:33	23:44:36	2	3
4	23:46:16	23:46:17	23:46:20	1	3
5	23:48:26	23:48:27	23:48:31	1	4
6	23:50:12	23:50:13	23:50:15	1	2
7	23:52:08	23:52:10	23:52:14	2	4
8	23:54:13	23:54:16	23:54:18	3	2
9	23:56:36	23:56:37	23:56:40	1	3
10	23:58:14	23:58:16	23:58:21	2	5
Average Delay				1.7	3.2

TABLE III. TESTING DELAY ON NODE 2

No.	**Time**			**Delay (second)**	
	Serial Monitor	***Database***	***Website***	***Serial Monitor-Database***	***Database -Website***
1	23:04:16	23:04:18	23:04:22	2	4
2	23:06:12	23:06:13	23:06:15	1	2
3	23:08:23	23:08:24	23:08:26	1	2
4	23:10:18	23:10:19	23:10:23	1	4
5	23:12:45	23:12:48	23:12:53	3	5
6	23:14:28	23:14:30	23:14:32	2	2
7	23:16:06	23:16:08	23:16:10	2	2
8	23:18:37	23:18:38	23:18:42	1	4
9	23:20:13	23:20:14	23:20:17	1	3
10	23:22:24	23:22:25	23:22:27	1	2
Average Delay				1.5	3

V. CONCLUTION

Based on the design, implementation, and testing of the system that has been made, conclusions can be drawn as follows. Based on several tests that have been carried out, the system created can facilitate the task of hospital employees to control the volume of patient infusion through the website.

In system implementation, the load cell sensor at node 1 has an average error value of 0.6%, while the load cell sensor at node 2 produces an average error value of 0.9%. Based on three tests carried out on node 1 and node 2 the sensor can function properly because it produces an error of less than 5%. Notifications to check the patient's infusion volume at node 1 and node 2 function properly when the infusion volume at each node reaches a value of 80 grams.

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