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Internet of things-based intravenous fluid monitoring system prototype and drops per minute control with MG996R servo

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Abstract

A medical device called an intravenous is used to restore electrolyte balance in hospitalized patients with various diseases by replacing lost fluids. When a patient has an emergency, such as dehydration, seizures, high fever, malaria, diarrhea, or other illnesses, an IV is usually required. In health facilities, the practice of intravenous monitoring by healthcare workers serves as an essential part of treatment. This is especially important because delays in intravenous changes or differences in intravenous flow rates in patients can be fatal to the treated patient. A system of tools is needed to facilitate nurses in monitoring the condition of the intravenous volume, and the number of intravenous droplets in the patient. Intravenous volume, the number of intravenous droplets per minute of the treated patient, and notification of intravenous fluid running out. This intravenous fluid monitoring system uses a Loadcell sensor to measure intravenous volume, an Infrared sensor to detect intravenous droplets, and an MG996r servo motor to adjust the speed of intravenous fluid drops automatically. The web monitoring platform of this system is used to display the condition of intravenous volume and droplets per minute in real time. From the test results, the average value of Loadcell accuracy in measuring the mass of objects on 25 data reaches 99.08% and the average value of the accuracy of the MG996r Servo in adjusting the speed of the intravenous drops on 5 test data reached 96.96%. The Liquid Crystal Display will display the volume of intravenous fluid, drop per minute (DPM), and counter, as well as the selected condition between adult or child, while the Web will display the volume of the intravenous fluid, DPM, and pop-up notification that the intravenous fluid will soon run out when the intravenous fluid read by loadcell less than 100ml.

Keywords

Intravenous, Loadcell, Infrared, Servo MG996r, Internet of things

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Introduction

An infusion device is used in hospitals to restore electrolyte balance in patients with various diseases by replenishing lost fluids. Infusions are typically required during emergencies such as dehydration, seizures, high fever, malaria, diarrhea, and other conditions [1][2]. They are essential for every patient admitted to a healthcare facility, such as a hospital, health center, or clinic. Infusion fluids are usually packaged in special plastic bags or bottles. Nurses are responsible for replacing intravenous fluids once they are depleted [3][4].

The advancement of technology in the 21st century has led to the development of tools and devices that facilitate human work, and infusion devices are part of this progress. As people continue to advance scientific knowledge and develop new tools, the efficiency and practicality of medical treatments are greatly improved [5].

Monitoring infusions in patients within healthcare facilities is crucial because it is a key aspect of patient treatment. Delays in changing an infusion or inconsistencies in the flow rate can lead to serious complications. For example, negligence in monitoring infusions once resulted in the death of an infant due to dehydration and breathing difficulties after the infusion bottle ran dry [6][7]. An infusion is a medical device to replace body fluids and balance electrolyte levels in hospitalized patients. If issues such as blockages or fluid depletion occur, and are not addressed promptly, they can pose serious risks to patients which lead to further complications. For instance, blood could be drawn into the infusion line and freeze, disrupting the flow of the infusion fluid.

Currently, infusion monitoring in general wards is still carried out manually, which can lead to errors. In many hospitals, the number of patients often exceeds medical staff, particularly in nursing, where staff are responsible for 24-hour patient monitoring [7][8]. This staff shortage increases the likelihood of oversight, especially regarding infusion monitoring. Nurses typically have to check the patient's infusion condition at predetermined intervals, requiring them to repeatedly visit the patient’s room [9].

This research aims to design a tool that can automatically monitor infusion fluids to reduce the likelihood of nurse negligence. The tool will allow real-time monitoring of the infusion fluid's condition, accessible remotely at any time, via a computer or smartphone in the nurse's station [10]. Several studies have focused on infusion fluid monitoring systems. For example, [11] designed a system that monitors and displays a patient’s infusion status in real-time. Their system uses an ATMega8535 microcontroller-based loadcell system (with a loadcell as a weight sensor) and an ESP8266 Wi-Fi module to transmit the data. Unlike previous research, this study measures only the infusion volume. The proposed research will utilize an IR photodiode sensor to monitor the drip rate, using a servo to control the flow speed [12][13].

IoT-based infusion monitoring tool integrates a web server to monitor infusion data and uses the free Telegram application to notify caregivers of each patient's infusion status. In their study, the device achieved 98.89% accuracy in monitoring infusion data. The proposed research will differentiate itself by automating the monitoring of the drip rate, with a focus on both adult and pediatric patients [14][15].

Additionally, explored IoT networks for data transmission, connecting to a Firebase database and using an Android-based application to control and monitor infusion data. The proposed study will further enhance this concept by automating the drip rate monitoring for different patient age groups, utilizing a web platform (PhpMyAdmin) and an LCD output [16][17].

Method

The research methodology used in this study is Research and Development (R&D). The research will begin by reviewing existing literature, identifying strengths and limitations of previous studies, and using these insights to inform the development of the proposed system. Next, data on the necessary components will be collected. Once all required components are obtained, the system design will proceed according to the planned specifications.

After the system and tool have been designed, testing will be conducted to verify that the system works as intended. The goal of the testing phase is to ensure that the design meets the objectives outlined in the planning stage. If the system does not pass the testing phase, further evaluation and adjustments will be made, including checking the circuit and the program code. The IoT-based infusion fluid monitoring system consists of both hardware and software components. The overall system design is illustrated in Figure 1.

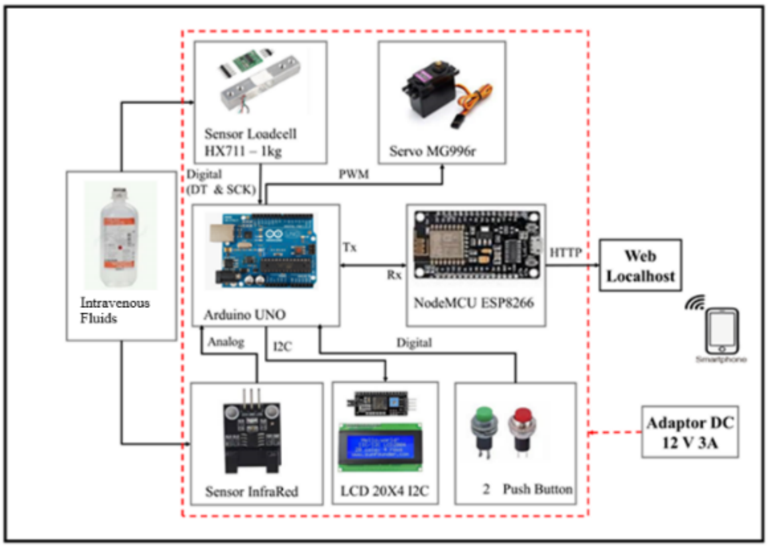

Figure 1. Wiring circuit

The flowchart begins by enabling Wi-Fi and connecting the NodeMCU ESP8266. Once the Wi-Fi connection is established, the IoT system and the entire system are initialized. When a 500ml infusion fluid bag is hung on the load cell, the load cell detects the volume of the infusion fluid. The IR sensor reads the infusion fluid droplets as they drip from the infusion bag into the patient's infusion set.

The 20x4 LCD, mounted on the infusion pole, will display the "Menu" option. The menu options can be navigated and selected using the push button. When the green push button is pressed once, the "Adult and Child" option will appear, then press the yellow push button to confirm "Ok".

Once the selection is made, the servo motor will adjust the infusion rate based on the initial menu option for setting the DPM (Drops Per Minute) speed through the servo motor's position. The LCD will display the DPM value, volume weight, and counter for the selected option. The web dashboard will show the infusion volume and DPM data. A pop-up notification will appear on the web interface when the infusion fluid volume falls below 100ml. Pressing both push buttons simultaneously will return to the main Menu.

Results and Discussion

Loadcell accuracy testing

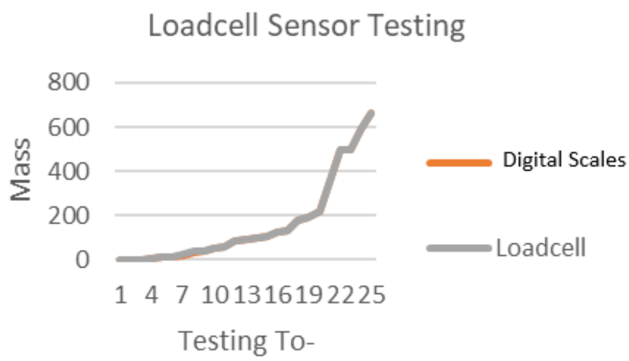

Figure 2. Loadcell sensor testing

Based on Figure 2, comparative testing of weight measurements using digital scales with Loadcell on 25 different types of objects has been carried out. The results of the analysis showed that the average accuracy in 25 Loadcell tests as a measurement detection was 99.08%. This result is obtained from mathematical calculations,

$$= 100\% - \frac{Error(\%)}{Amount\ of\ data\ (n)} \quad (1)$$

$$= 100\% - \frac{23{,}24(\%)}{25}$$

$$= 100\% - 0{,}92\%$$

$$= 99{,}08\%$$

The minimum measurable weight of the digital scale is 5 grams, while the minimum measurable weight of the load cell is 1 gram. Therefore, a weight of 1 gram on the load cell will not be detected by the digital scale. Weights under 1 gram will not be recognized by the load cell on the serial monitor, and will be recorded as 0. The load cell used has a capacity of 1 kg, with a measurement range from 0 to 1 kg. While the load cell can technically measure up to 3 kg, its accuracy diminishes beyond the 1 kg range. The graph demonstrates that both the digital scale and load cell sensors exhibit high accuracy and low error, as indicated by the nearly identical lines.

IR photodiode testing based on MG996r servo motor accuracy

Testing the Photodiode IR Sensor based on the accuracy of the MG996r servo motor is done by dripping infusion fluid at a speed regulated by a servo motor with different degrees. The infusion speed will be adjusted to the infusion fluid needs of the treated patient. The test results are shown in Table 1 and Table 2.

Table 1. IR sensor and servo testing results based on patient needs

No	Servo Motor Degree (Speed Reading)	Drops per Minute (DPM)	Patient Needs	DPM Required
1	55 degree	19 dpm	Child <5 y.o. 1,300 ml	18 dpm
2	60 degree	27 dpm	Adult >5 y.o. 2,000 ml	20 dpm

The results of testing the IR sensor MG996r servo motor accuracy, that from the calculation of water needs in the body:

a. Children < 5 years old:
   Requires 1,300 ml
   The infusion fluid used in the research is 500 ml with a drip factor of 20 drops over 9 hours.
   Total TPM for children = (500 ml x 20 drops)/(9 x 60) = 18 tpm
   To be able to achieve fluid requirements, pediatric patients need 2 bags of ½ NaCl @ 500 ml
b. Adults > 5 years of age: Requires 2,000 ml
   The infusion fluid used is 500 ml with a drip factor of 20 drops over 6 hours.
   Total Adult TPM = (500 ml x 20 drops)/(6 x 60)= 28 tpm
   To achieve fluid requirements, adult patients need 4 NaCl bags @ 500 ml.

Table 2. IR sensor testing results based on MG996r servo motor accuracy

No	Servo Motor Degree (Speed Reading)	Drop per Minute (DPM)				Average of DPM = ∑DPM/4	Error (%)	Accuracy (%)
		1	3	5	7			
1	50 degree	10 dpm	12 dpm	9 dpm	10 dpm	10.25 tpm	8.53%	91.47%
2	55 degree	18 dpm	19 dpm	19 dpm	19 dpm	18.75 tpm	2.00%	98.00%
3	60 degree	27 dpm	28 dpm	28 dpm	26 dpm	27.25 tpm	2.75%	97.25%
4	70 degree	45 dpm	46 dpm	45 dpm	45 dpm	42.25 tpm	0.82%	99.18%
5	90 degree	87 dpm	89 dpm	86 dpm	88 dpm	87.50 tpm	1.14%	98.86%
						Average Error (%)	3.04%	
						Accuracy (%)		96.96%

Localhost testing

Localhost Web testing is intended to find out what will be displayed when the infusion device system is running. The test results can be seen in Figure 3, Figure 4, Figure 5, and Figure 6.

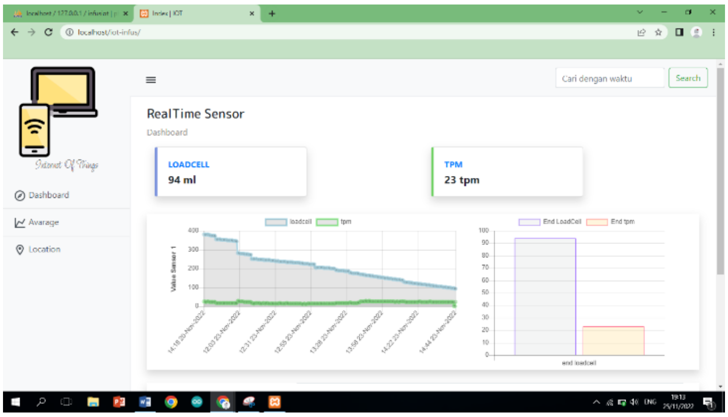

Figure 3. Main view of web dashboard

In the Localhost Web Dashboard view, the main display of the web dashboard TPM graph is shown by the green color line and the infusion volume graph measured by the Loadcell is shown by the blue color line.

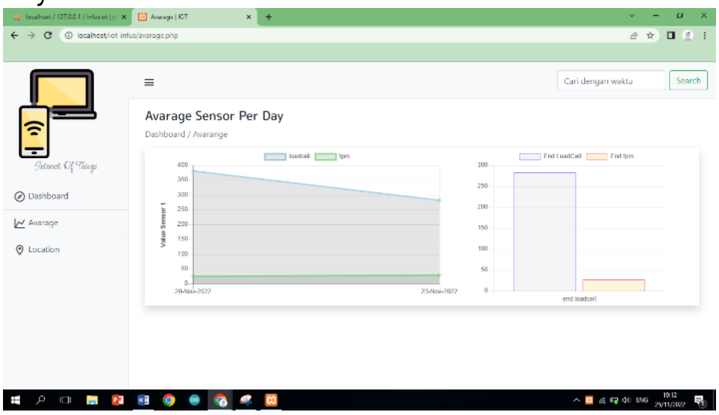

Figure 4. Sensor avarage per day (loadcell and TPM)

Figure 4 displays the Internet of Things web average which shows the TPM graph and the highest total infusion volume per day. The TPM graph is shown by the green color line and the infusion volume graph measured by the Loadcell is shown by the blue color line.

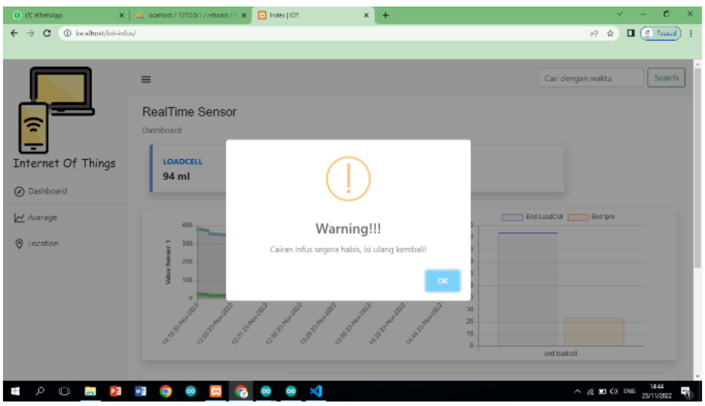

Figure 5. Infusion fluid notification display running out soon

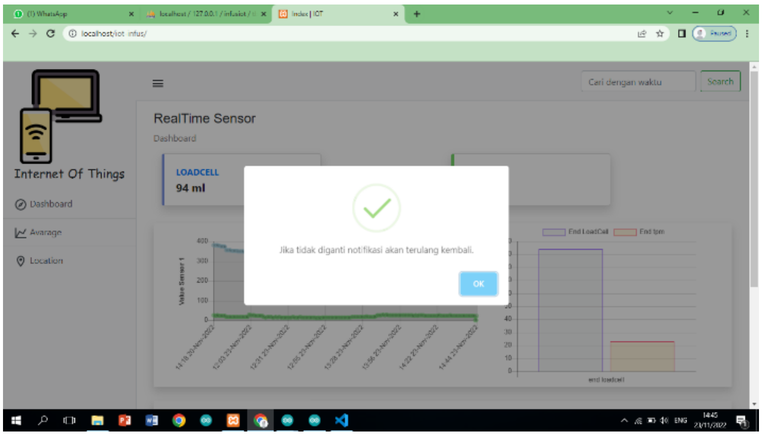

Figure 6. Notification display when the infusion bag is replaced

Figure 6 shows that notifications will continue to appear without interrupting the calculation of weight and tpm. When the notification appears and only pressed "Ok" without being replaced, it will continue to display the notification as in Figure 5. When the infusion fluid has been replaced, the notification will automatically disappear.

Accuracy of the tool system

The accuracy testing of the tool aims to determine whether the device produces the expected output. This includes testing the volume of infusion fluid and the DPM (Drops Per Minute). The comparison in this test is made between the data displayed on the LCD monitor and the web interface. The accuracy testing is performed using a program in the Arduino IDE. Two programs are used: one for the transmitter (Tx) on the Arduino Uno, which sends data to the NodeMCU ESP8266 acting as the receiver (Rx).

Testing the suitability of the infusion liquid volume display

Testing the accuracy of the infusion fluid volume aims to determine whether the volume of infusion fluid measured by Loadcell is the same between what is displayed on the LCD monitor of the Arduino Uno and the display on the web monitor. The following LCD display and web monitoring system are shown in Figure 7 and Figure 8.

Figure 7. infusion fluid volume display on LCD

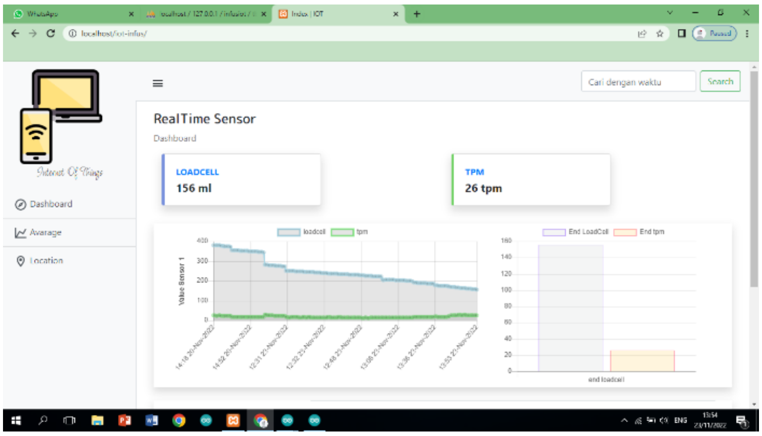

Figure 8. Infusion liquid volume display on the web dashboard

Based on testing the accuracy of the infusion fluid volume on the LCD connected to Arduino Uno and the web dashboard that has been done, it can be seen that the difference value of the volume data is 0. This proves that the accuracy level of the Arduino Uno LCD volume and the web dashboard is 100%.

Infusion fluid TPM accuracy testing

Testing the accuracy of the infusion fluid TPM aims to determine whether the infusion fluid TPM measured by the IR sensor is the same between what is displayed on the Arduino Uno LCD monitor and the display on the web monitor. The following LCD display and web monitoring system are shown in Figure 9 and Figure 10.

Figure 9. Infusion fluid TPM display on LCD

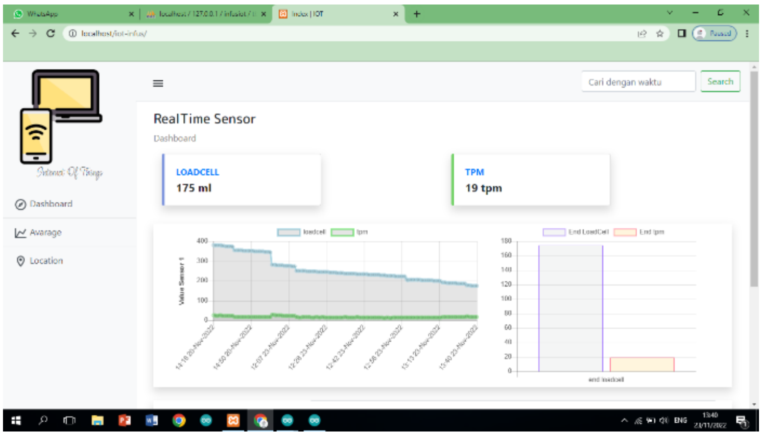

Figure 10. Infusion liquid volume display on the web dashboard

Based on testing the accuracy of the infusion fluid TPM on the LCD connected to Arduino Uno and the web dashboard that has been done, it can be seen that the difference value of the TPM data is 0. This proves that the accuracy of the TPM LCD Arduino Uno and the web dashboard is 100%.

Conclusion

After designing, developing, and testing the Internet of Things-based Intravenous Fluid Monitoring System Prototype and Drops Per Minute Control with MG996R Servo, the following conclusions can be drawn:

a. The IoT-based infusion fluid monitoring system has been successfully created. The volume of the infusion fluid is accurately measured using the load cell, and the drops per minute (DPM) are successfully detected by the IR sensor. The drip speed is controlled by the servo motor, and the output results are displayed on both the LCD and the web monitor, which can be accessed via a browser on a PC or smartphone.

b. The testing of the drops per minute (DPM) speed using the MG966R servo achieved the desired range for both adult and child conditions, with 19 DPM for children and 27 DPM for adults.

c. The average accuracy of the load cell in measuring the mass of objects across 25 different test samples is 99.08%, while the average accuracy of the MG966R servo in controlling the infusion drop speed across 5 different tests is 96.96%.

d. The LCDs the infusion fluid volume, DPM, counter, and the selected condition (Adult/Child), while the web monitor displays the infusion fluid volume and DPM. A pop-up notification will appear on the web interface when the infusion fluid volume, as detected by the load cell, falls below 100 ml, indicating that the infusion is running low. This notification will persist until the nurse replaces the infusion.

e. The communication between the Arduino Uno and NodeMCU ESP8266 is established using serial communication, while data transmission from the

NodeMCU ESP8266 to the web monitor is done via HTTP over an Apache2 network.

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