Journal of Applied Engineering and Technological Science
Vol 5(2) 2024: 649-660

MICROCONTROLLER-BASED INTRAVENOUS FLUID MONITORING SYSTEM DESIGN

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Received : 8 September 2023, Revised: 26 December 2023, Accepted : 29 December 2023
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ABSTRACT
Intravenous fluids are used to replace the body's fluid and electrolyte balance. This is a crucial need for a patient during treatment, so infusion replacement should not be delayed as it can be fatal to the patient. Medical personnel must always pay attention to the patient's infusion. This has always been a problem because the limited number of medical personnel and the large number of patients often make it difficult for medical personnel to carry out their duties. The development of technology increases human creativity and creates various tools to help humans be more effective, including in dealing with problems in the medical world. Based on this background, the author designed an infusion fluid monitoring system to facilitate nurses in hospitals that lack electrical support and internet networks. This research aims to make an intravenous fluid monitoring tool using a microcontroller effectively and realtime. The research method we use is research and development, while the data analysis method uses comparative quantitative analysis. This research consists of three main parts, namely system input, microcontroller as system processor, and system output as expected. This infusion fluid monitoring uses Load Cell to measure the volume of infusion fluid, RTC module to estimate the time of infusion fluid expiration, LCD as infusion fluid status information, and buzzer as an information alarm if the infusion fluid is detected to run out. The microcontroller used in this research is Arduino Uno. The results showed that infusion fluid has the same pressure as human body fluids (isotonic). Load Cell has a mass reading accuracy value of 99.88%, the accuracy of testing the conversion of intravenous fluid measurements into milliliters of 99.49%, and the number of infusion fluid droplets per minute under normal conditions is 20, with an estimated time out for 8 hours.
Keywords : *Load Cell, RTC, Intravenous Monitoring, Buzzer*

1. Introduction

Today's technological developments and advances increase human creativity in creating various devices that can help and support work to be more efficient and practical (Polderman et al., 2017). This technology's development can benefit humans if its application is done correctly (Wang & Jiang, 2018)(Lu & Mao, 2023). Based on this, technology is also very much needed in the medical world (Naeim et al., 2023). This is driven by the condition of healthcare facilities such as hospitals (Amano et al, 2012), health centers, and polyclinics (Jianwen & Han, 2011). The large number of patients but the limited number of medical personnel (Jianwen & Han, 2011) is a problem in providing the best service, one of which is handling patients intravenous(Gabriel et al., 2023).

Intravenous is one of the primary therapies given in hospitals (Giaquinto et al., 2021). Intravenous is a medical device that, under certain circumstances, is used to replace lost body fluids and balance electrolytes in the body (Alagundagi et al., 2018; Chen et al., 2015; Xinling, 2008); for example, in emergency conditions when the patient is dehydrated, excessive metabolic stress results in hypovolemic shock, acidosis, gastroenteritis, scarlet fever, burns, hemorrhagic shock, and trauma. The intravenous also has been used as an initial solution for the electrolyte status of patients not yet known, such as cases of dehydration due to inadequate oral intake, fever, and so on (Gawronska et al., 2023).

Replacement of intravenous fluids should not be late (Caya et al., 2019; Venkatesh et al., 2022) because it can be fatal for the patient; one of the fatal incidents due to the negligence of nurses at the Pangkal Pinang General Hospital, Bangka Belitung, was the death of a 4-day-old baby due to delays in changing the intravenous which resulted in the baby having difficulty breathing and malnutrition. A lot of fluid due to the intravenous attached to the baby's body is dry (Noel-Weiss et al., 2011). Medical personnel must always pay attention to the patient's intravenous. This is always a problem because the limited number of medical personnel and many patients often make it difficult for medical personnel to carry out their duties. Infusion is one of the medical devices that in certain circumstances is used to replace lost body fluids and balance electrolytes in the patient's body. Infusion fluid replacement should not be late, as it can be fatal to the patient, so the ratio of nurses is crucial. Based on data from the Yogyakarta City Health Office in 2021, there were 87 nurses in 18 health centers in Yogyakarta City. The average number of nurses in one health center is 3 to 4 people even though based on the Regulation of the Minister of Health R.I. Number 75 of 2014 the standard is 5 nurses. Based on this background, the author conducted research on designing a microcontroller-based infusion fluid monitoring system as an early warning to facilitate nurses in monitoring patient infusions. This research is in line with the Master Plan for Smart City Development (Smart City) in Yogyakarta City in 2018-2022 which includes 6 (six) elements, namely smart governance, smart branding, smart economy, smart society, smart living and smart environment where one of them is smart living which emphasizes on guaranteeing health facilities and services.

2. Literature Review

Some studies related to intravenous fluid monitoring systems, including as described below, (Zhang et al., 2010) the design and implementation of a novel wireless sensor network for intravenous infusion monitoring based on slot-coupled infrared emitting diode as sensors, chip ATMEGE128L as MCU and chip CC2420 as ZigBee-based RF communication (Choudhury et al., 2015). The system has following characteristics: non-touch droplet monitor, easy to reuse, multiple protections on system accuracy and reliability, easy to integrate with existing hospital management system due to flexible design of the host computer software, low cost, and easy to launch large-scale applications.

Designing an intravenous monitoring system based on the Wemos D1 R2 microcontroller (Swedarma et al., 2023)(Chiradeja & Yoomak, 2023). This research has successfully produced a tool to provide information about the remaining intravenous fluids through Arduino IDE serial monitoring. The similarity of this previous research with the research that the author will do is both use a Load Cell weight sensor, but what makes the difference is that previous studies used the ESP8266 Wi-Fi module for remote monitoring of the remaining intravenous fluids. In contrast, the authors will use the LCD output and buzzer to notify the nurse. This difference minimizes Wi-Fi network constraints in rural areas lagging in Internet network access.

Design of an intravenous monitoring and control system with the application of the Android-based Internet of Things (IoT) (Boikanyo et al., 2023)(Ayumi, 2019). This study aims to monitor blood clots in inpatient intravenous s by applying the Internet of Things concept. The results of the research test of this system can stabilize the drip with the application of the Internet of Things. This study and the author's research are similar in that they both use a Load Cell weight sensor. Still, the difference is that previous studies did not use a buzzer as the output and focused more on facilitating the rate of intravenous fluid.

Monitoring and warning system on patient intravenous fluid volume (intravenous) using website-based Arduino (Sifa Fauziyyah & Yohandri, 2020). This study has succeeded in monitoring the condition of the patient's intravenous fluid with a real-time website interface. The novelty of this research is the existence of a website interface as an alarm warning for the volume of intravenous fluids (Hardi et al., 2020). Barriers in rural areas that are still far behind in internet access are why the author uses a buzzer (Laukkanen et al., 2021) as an alarm for notification of the remaining volume of intravenous fluid and not a website like previous studies. This research is also based on the internet of things so that in addition to monitoring the condition of intravenous fluid availability, it can also record monitoring data from time to time.

Monitoring intravenous fluids based on condition indicators and rates using a Wi-Fi network (Majid et al., 2021). This system research produces a real-time tool that can monitor the patient's intravenous fluids through computers and smartphones (Fajrin et al., 2022). There are differences in the components that the author will use in conducting further research; namely, the author will use a weight sensor to determine the volume of intravenous fluid, while this study uses a potentiometer to measure the volume of intravenous. The author chose a weight sensor to minimize errors in measuring the volume of intravenous fluids.

The purpose of this research is to create a system for real-time and accurate intravenous fluid monitoring with complete information including the current volume of intravenous fluid, droplets per minute, and the duration of time until the fluid runs out (Kroeger et al., 2006)(Martinsen et al., 2020). In addition, the monitoring system is also designed based on the internet of things so that it can be accessed from anywhere and the data can be recorded from time to time.

This research includes experimental with loadcell testing using mass variations, testing changes in load cell sensor voltage using a digital multimeter, drops per minute comparing the value of drops in the system and natural conditions in one minute, testing the accuracy of the RTC module in calculating time. In addition, the conversion of infusion fluid measurements from mass to volume using a load cell was also tested. The conversion from mass to volume is done by using the formula for the density of intravenous fluid, which is 0.9%. In collecting data in this study, it has not been used on actual patient research objects, because it is still in the prototype stage. Testing is intended to test the accuracy and effectiveness of the system with the various tests above. In the data analysis process, the author uses quantitative methods with comparisons, comparing the data generated by the system with measuring instruments that have been tested and calibrated properly.

3. Research Methods

Intravenous

Intravenous is a sterile preparation of a solution or emulsion, free of pyrogen and, as much as possible, made isotonic to blood, injected directly into a vein with a relatively large volume (Czerniel et al., 2023). Preparation of preparations to be used for intravenous must be done carefully to avoid microbial contamination and foreign materials (Lu & Mao, 2023). How to adjust the speed of the intravenous rate is as follows

$$\text{ml/hours} = \text{drops per minute} * \text{drop factor} \quad (1)$$
$$\text{drop factor} = 60/\text{w} \quad (2)$$

w is the number of drops expelled by the intravenous to dispense 1 mL of fluid.

Arduino Uno

Arduino Uno is an Atmel AVR microprocessor where the microcontroller board is installed ATmega328 in it (Bisták, 2019). This device can function to run simple to complex electronic circuits. Arduino Uno has 14 digital input/output pins, six pins are used as analog circuits, a USB connection, a power jack, an ICSP header, and a reset button (Abolore et al., 2024). Arduino Uno contains everything needed to support the microcontroller (Kvalsund & Winkler, 2023). You can connect it to a computer with a USB cable, supply it with an AC to DC adapter, or use a battery to get started.

Load Cell

Load Cell is an electronic component that is used to measure pressure (Santos et al., 2023). The working principle of this sensor is when the object is exposed to pressure, the foil or wire will be deformed so that the threads will be stretched lengthwise (Chen et al., 2015). When this happens, the threads become longer and thinner, increasing their electrical resistance. The Load Cell sensor in this study measures the volume of intravenous fluid. The Load Cell sensor used has a weight capacity of 1 kg and has a working principle based on the Wheatstone bridge.

The Wheatstone bridge is the basis for several electronic circuits, including some used in instrumentation and measurement (Mantenuto et al., 2012; Talić et al., 2009).

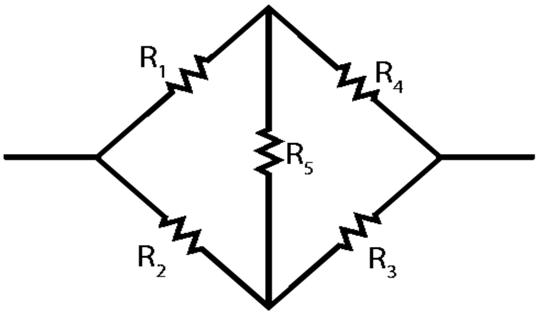

Fig. 1. Wheatstone Bridge Circuit

The formula used in the Load Cell working principle to get the Vout value, which is as follows,

$$Vo = \left(Vs\ x\ \left(\frac{R1}{R1+R4}\right)\right) - \left(Vs\ x\ \left(\frac{R2}{R2+R3}\right)\right) \qquad (3)$$

Methods

This research is designed to create an intravenous fluid monitoring system to assist medical personnel in performing their duties. This research is expected to be helpful in underdeveloped areas still constrained by the internet network and electricity supply. This study designed a monitoring system that can be connected to the supply of electricity and also the battery supply. This monitoring system uses a Load Cell sensor, which is used to measure the volume of intravenous fluid. Then, this system uses the Real Time Clock (RTC) module to estimate when the intravenous fluid runs out. It also uses a buzzer as a warning alarm when the intravenous fluid is detected running out in the nurse's room.

The research method that will be used in this final project is Research and Development (R&D). The R&D method is research that is used to produce specific products and test the effectiveness of these products (R & Susanti, 2019). This research begins by collecting sources of previous research, looking at any shortcomings or advantages of previous research, and then developing it in the research the author will conduct. The purpose of this research is to produce a product where the resulting product already exists, and the product is made to be perfected so that it can be used to support the development of technological innovation in the field of biomedical instrumentation.

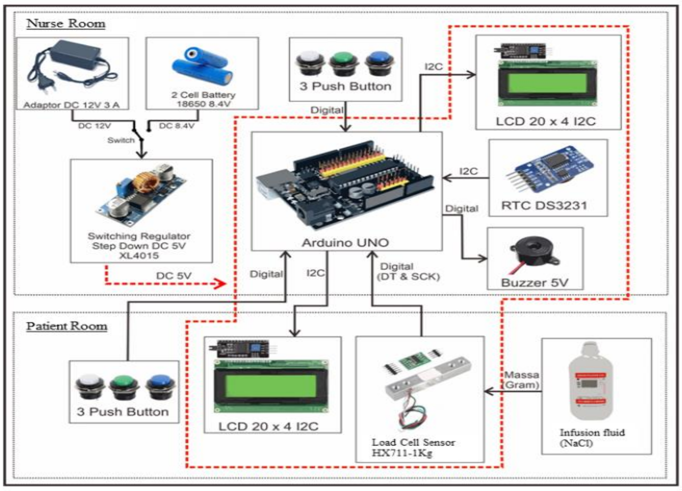

Fig. 2. System Process Diagram

Figure 2. is a block diagram of the intravenous fluid monitoring system design that will be made. The design block diagram generally consists of 3 parts: input, processing, and output. The input to this system is the Load Cell sensor, which gets the volume value from the NaCl intravenous fluid. The processing of this system is Arduino Uno, and the output of this system is

a 20x4 LCD and buzzer. Liquid Crystal Display or LCD is a screen that uses liquid crystals as its main viewer (Roohani et al., 2023) The working system of this tool starts when the voltage is supplied by a 12 V DC adapter or an 8.4 V battery and is lowered to a working voltage of 5 V DC by a step-down regulator so that the system can work optimally when the tool is on. The intravenous fluid has been hung on the Load Cell sensor. Then, the sensor measures the volume of the intravenous fluid and sends the volume data to the Arduino Uno microcontroller for later processing and display on the 20x4 LCD.

After that, the push button will be activated to run the monitoring system. The RTC module (Bruscato et al., 2016) , which has previously counted the time when the voltage is applied and has displayed the current time display (WIB) on the LCD, will send data about when the intravenous fluid will run out. Arduino Uno will display it on the LCD. The Load Cell sensor will continuously weigh the volume of the intravenous fluid and send its data to the Arduino Uno until reaches the threshold volume previously programmed in the Arduino IDE. It will activate the buzzer as a warning alarm for nurses.

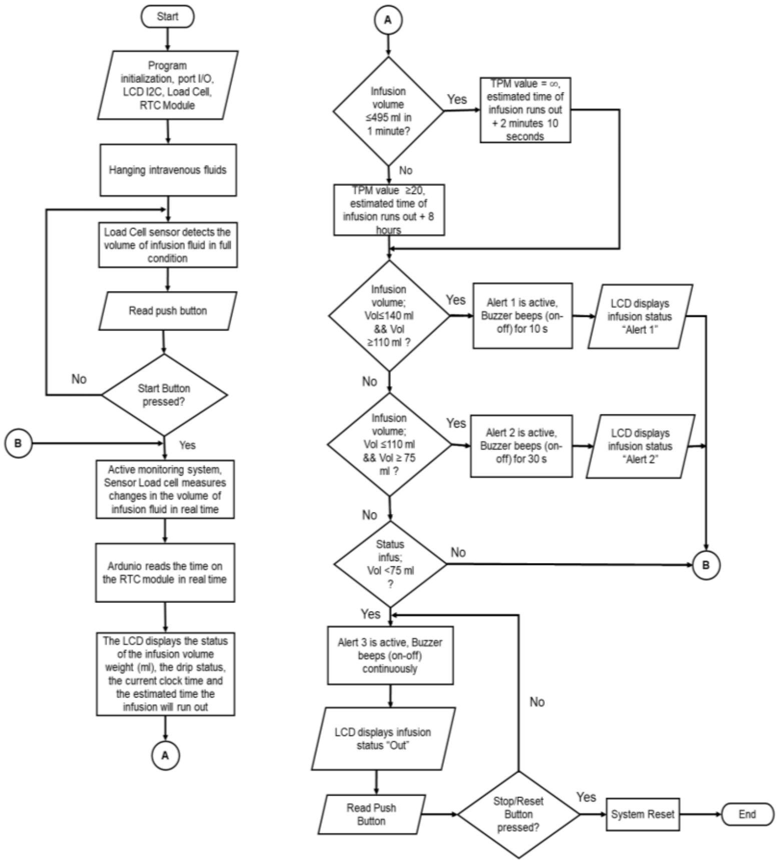

Fig. 3. System Algorithm

Figure 3. The system algorithm of the intravenous fluid monitoring system, the flow diagram starts with initializing program variables, setting input-output ports, LCD 12C library, Load Cell sensor library, and RTC module library used. After this, the nurse will install or hang the 500 ml NaCl solution bottle on the intravenous pole connected to the Load Cell sensor. After the Load Cell sensor has detected and read the total volume of the intravenous fluid, the nurse will install the intravenous set on the patient and will activate the monitoring system by pressing the button on the push button. The monitoring system will be active, the Load Cell sensor will continuously measure weight changes that occur in the volume of the intravenous bottle, and the RTC module will count the time continuously to compare changes in the volume of intravenous fluid volume reduction to the RTC set point that has been programmed so that the RTC will be able to Estimate the intravenous time out. The 20x4 shows information indicators regarding the weight status of the intravenous volume in ml, the current hour (WIB), the estimated time the intravenous will run out, and the number of drops per minute. When the intravenous volume is ≤495 ml in one minute, intravenous drops/ minute = ∞ and the estimated

time is ±2 minutes 10 seconds. However, if the intravenous flow is expected, the intravenous drops/ minute value is ≥20, and the estimated time is only 8 hours. This is evidenced in the table for testing the number of intravenous drops/ minute 10 times. The following data collection is provided in Table 1.

The Load Cell sensor will perform repeated measurements until the volume of the intravenous fluid reaches the threshold limit. The intravenous will run out, which is programmed in the Arduino IDE application. When the intravenous fluid volume is ≤140 ml & ≥110 ml, the buzzer will beep (on-off) for 10 seconds. The intravenous status will be displayed as Alert 1 on the LCD when the intravenous fluid volume is ≤110ml & ≥75 ml. The buzzer will beep (on-off) for 30 seconds with an alert display 2. Finally, if the condition of the intravenous volume is <75 ml, the buzzer will sound continuous, and the LCD will display the status of the intravenous running out. The buzzer can be stopped by pressing the push button stop, and the push button starts to repeat the initial step of reading the system.

Table 1 - Test Data Intravenous Drops/ Minute

Item	Volume (ml)	Drops/ Minute	Reduced Intravenous Fluids
1	402	20	1 ml
2	401	20	1 ml
3	400	20	1 ml
4	399	20	1 ml
5	398	20	1 ml
6	397	20	1 ml
7	396	20	1 ml
8	395	20	1 ml
9	394	20	1 ml
10	393	20	1 ml

4. Results and Discussions

Load Cell Sensor Test

This Load Cell sensor test aims to see the accuracy of the Load Cell sensor, which is used as a sensor that will be used to measure the weight of the intravenous. This test includes the measurement of several objects that have the smallest to the most enormous mass in grams, which later the test results will be compared with the reference weight. Where the reference weight comes from a conventional scale, the object to be weighed using a load cell was previously weighed with a conventional scale.

The minimum load cell measurement is 1 gram because if you take measurements below 1 gram, the load cell cannot display the measurement results, or what is read on the LCD or serial monitor is 0. Meanwhile, the maximum load cell measurement reaches 3 kg, but the results are not accurate again because the Load Cell used is a 1kg Load Cell; that Load Cell is only accurate at 0-1kg workloads. This follows what is described in the Load Cell data sheet, where the Load Cell is capable of being accurate when working at maximum load per the Load Cell specifications used (Santos et al., 2023).

Table 2 - Load Cell Measurement Accuracy

Item	Digital Scales Weight (Grams)	Load Cell Weight (Grams)	Error	Accuracy
1	50	49	1	98%
2	80	81	1	98.75%
3	110	110	0	100%
4	140	141	1	99.29%
5	170	170	0	100%
6	200	200	0	100%
7	230	231	1	99.57%

8	260	260	0	100%
9	290	290	0	100%
10	310	310	0	100%
11	340	340	0	100%
12	370	370	0	100%
13	400	400	0	100%
14	430	430	0	100%
15	460	460	0	100%
16	490	490	0	100%
17	510	510	0	100%
18	540	540	0	100%
19	570	570	0	100%
20	600	601	1	99.83%
	Average of Accuracy			99.88%

In this first test, the author tested the accuracy of the load cell as a weight sensor compared to a calibrated digital scale. In 20 tests, the loadcell accuracy rate was 99.88%, so it can be said that the loadcell in measuring weight has a high level of accuracy and only has an error rate below 0.2%. This strengthens when using a loadcell to weigh the intravenous fluid load that is hung on the sensor will produce an accurate value and can be used to convert it to its volume through the density formula.

Infusion Fluid Measurement Conversion Testing

This infusion fluid measurement conversion test is carried out to see changes in infusion fluid measurement results in units of grams to ml (Smith et al., 2022). This is done because the Load Cell sensor can only measure the mass of objects. If you want to display ml units to the LCD, you must first know the difference in infusion fluid measurements using conventional scales that are the same as the Load Cell sensor and measure the volume of liquid in ml units using a measuring cup. This test aims to determine whether the infusion fluid requires a density change formula or not because it is isotonic with the human body. Isotonic is a solution whose solute concentration is the same as the fluid in human body cells. The following table shows the results of the infusion liquid conversion test in grams to ml, shown in table 3.

Table 3 - Infusion Fluid Measurement Conversion in Mili liter

Test	Infusion Liquid Reference Weight (ml) (Measuring Cup)	Infusion Liquid Weight (ml) (Load Cell)	Error	Accuracy
1	50	2%	2%	98%
2	100	2%	2%	98%
3	150	0%	0%	100%
4	200	0%	0%	100%
5	250	0%	0%	100%
6	300	0%	0%	100%
7	350	0,60%	0,60%	99,4%
8	400	0,50%	0,50%	99,5%
9	450	0%	0%	100%
10	500	0%	0%	100%
	Average		0,51%	99,49%

After converting grams to ml units on the Load Cell, the data is obtained according to table 3 above. Previously, the infusion liquid was poured into a measuring cup, then weighed on a conventional scale. After obtaining the measurement results, measurements are taken again with the Load Cell to compare the Load Cell measurement results with conventional scales because Load Cell can only read weight measurements in gram units. Only then are the measurement results converted into ml units to be displayed on the LCD. The results of infusion fluid measurements are almost the same as weight measurements even though if reviewed the density of the infusion used (Sodium Chloride) is not the same as the density of water, this happens because the infusion fluid has been changed in compounds to be isotonic with the human body. So that the infusion liquid is almost the same as water and produces an infusion liquid density of 0.9% which is explained on the outer packaging of the infusion bottle. For this reason, the conversion of infusion fluid does not require the mathematical formula for the density of NaCl, but follows the conversion of water. Based on the ten times volume testing that the author has done above, the accuracy value of converting the load cell measurement value in millimeters is 99.49% with an error rate of 0.51%. This proves that the intravenous fluid measurement conversion process has a high level of accuracy.

Load Cell Sensor Voltage Change Test

Testing the change in voltage of the Load Cell sensor uses a digital multimeter, which aims to measure the excitation voltage and output voltage with units of volts DC sensor Load Cell when a load is given (Ligęza, 2022). The test was carried out when the intravenous load was given 0-500 ml with a range of 50 ml. The results of this test will later be analyzed as the relationship between the load given to the load cell and the measured voltage. This is done to see if the load affects the resulting voltage.

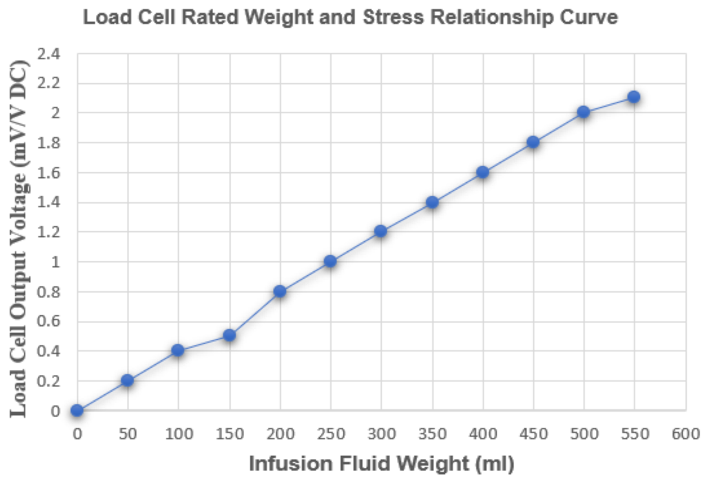

Fig. 4. Load Cell Volume and Voltage Relationship Curve

Table 4 - Load Cell Measurement Accuracy

Item	Intravenous Weight (ml)	Excitation Voltage (v DC)	Output Voltage (mv/ Dc)
1	0	4.5	0
2	50	4.5	0
3	100	4.5	0
4	150	4.5	0
5	200	4.5	0
6	250	4.5	1
7	300	4.5	1
8	350	4.5	1
9	400	4.5	2
10	450	4.5	2

Table 4 displays the relationship between the weight and the measured voltage on the Load Cell, where the heavier the measured load, the higher the output voltage read. Load Cell 1 kg has a maximum output voltage of about 1mV/V to 3 mV/V with an excitation voltage of 5 V DC, while the measured is 4.5 V DC. Load Cell output depends on the weight of ‘the load and the excitation voltage. Load Cell output is a signal sent from the Load Cell. The specification of the Load Cell’s output voltage is in mV/V because it relates to the mathematical calculation of the Load Cell’s output.

Intravenous Test Drops/ Minute

This drop-per-minute test compares the value of drops in the system and natural conditions in one minute. This test places the intravenous set roll position under normal conditions. The difference is that the drops/ minute intravenous flow system is released just like that, while the natural drops/ minute intravenous flow is channeled into teaching materials that have been shaped in such a way as to resemble the function of a human vein. This teaching aid is made from sponge and chamois. This happens because of limited costs when buying hand puppet mannequins and limited knowledge if you have to use real humans. The test results under standard conditions show that the number of system drops/ minute and standard drops/ minute is the same, namely 20-21 drops per minute, but outside of that condition, the system can no longer detect because of the limitations of the components used. Where count drops per minute, it takes an LDR sensor, while the problem limits the author to only use a Load Cell sensor.

RTC (Real Time Clock) Modul Accuracy Test

This test was conducted to test the accuracy of the RTC module in counting time. Tests are compared with wall clocks and clocks on smartphones. This test compares the results of alarm measurements using the RTC module and smartphone alarms. Then, test the RTC in seconds with the stopwatch on the smartphone. The test obtained from Table 5 shows that the RTC module can accurately count time and accurately display the clock's current condition.

Table 5 - RTC Accuracy Test

Set Buzzer Alarm Module RTC	Buzzer Alarm Sounds	Set Smartphon e Alarm	Alarm Stop RTC= Smartphone Alarm
11:58	Yes	11:58	yes
12:05	Yes	12:05	yes
12.30	Yes	12:30	yes

Table 6 - The Comparrison of the RTC Module and Smartphone

No	Time Set Stopwatch RTC	Stopwatch stop dengan smartphone
1	00.20	00.19
2	00.30	00.29
3	00.40	00.39
4	01.00	00.59
5	2:00	01.59
6	05.00	05.00
7	10.00	09.59

Tests that have been obtained from tables 5 and 6 show that the RTC module can count the time accurately, and can display the current clock conditions accurately. This will ensure the accuracy of the RTC in sounding the buzzer precisely and according to the time.

From the five tests that have been carried out, which show the level of accuracy in measuring intravenous fluid load, converting to volume values, measuring voltage, to the accuracy of RTC timekeeping, it can be said that the system will assist nurses in monitoring the intravenous fluid situation of patients in a ward. The system also facilitates the presence of a buzzer as an early warning that will turn on three times before the intravenous fluid completely runs out. This will prevent running out of intravenous fluids in every patient which has a dangerous and fatal risk for patient safety. In contrast to previous research [12,13,14], this research is expected to be helpful in underdeveloped areas still constrained by the internet network and electricity supply. This study designed a monitoring system that can be connected to the supply of electricity and also the battery supply.

5. Conclusion

In this research, we designed a microcontroller-based intravenous fluid monitoring system with an Arduino Uno microcontroller, a Load Cell as a weight sensor, an RTC module as a timer, and a buzzer as a warning alarm. Load Cell has a mass reading accuracy value of 99.88%, the accuracy of testing the conversion of intravenous fluid measurements into milliliters of 99.49%, and the number of infusion fluid droplets per minute under normal conditions is 20, with an estimated time out for 8 hours. The system also facilitates the presence of a buzzer as an early warning that will turn on three times before the infusion fluid is completely depleted. This will prevent the infusion fluid from running out on each patient which has a dangerous and fatal risk for patient safety. Unlike previous research, this research is expected to help in underdeveloped areas that are still constrained by internet networks and electricity supply because it is also connected to a battery supply

Acknowledgement

I would like to express my special gratitude and thanks to *Direktorat Riset, Teknologi, dan Pengabdian Kepada Masyarakat* (DRTPM) for the research grants with contract number 181/E5/PG.02.00.PL/2023; 0423.11/LL5-INT/AL.04/2023/ and thanks to Universitas Ahmad Dahlan for their support.

References

Abolore, A., Olurotimi, D., Edward, O., Olajumoke, H., & Nihinlola, F. (2024). e-Prime - Advances in Electrical Engineering , Electronics and Energy Arduino microcontroller based real-time monitoring of haemodialysis process for patients with kidney disease. *E-Prime - Advances in Electrical Engineering, Electronics and Energy*, *7*(November 2023), 100403. https://doi.org/10.1016/j.prime.2023.100403

Alagundagi, S. S., Pasala, K., & Arora, M. (2018). Opto-electronic system for intravenous infusion monitoring. *2018 10th International Conference on Communication Systems and Networks, COMSNETS 2018*, *2018-Janua*, 688–692. https://doi.org/10.1109/COMSNETS.2018.8328296

Amano, H., Ogawa, H., Maki, H., Tsukamoto, S., Yonezawa, Y., & Caldwell, W. M. (2012, August). A remote drip infusion monitoring system employing Bluetooth. In *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 2029-2032). IEEE.

Ayumi, V. (2019). Mobile Application for Monitoring of Addition of Drugs to Infusion Fluids. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, *5*(6), 48–56. https://doi.org/10.32628/cseit195616

Bisták, P. (2019). Arduino Support for Personalized Learning of Control Theory Basics. *IFAC-PapersOnLine*, *52*(27), 217–221. https://doi.org/10.1016/j.ifacol.2019.12.759

Boikanyo, K., Zungeru, A. M., Sigweni, B., Yahya, A., & Lebekwe, C. (2023). Remote patient monitoring systems: Applications, architecture, and challenges. *Scientific African*, *20*. https://doi.org/10.1016/j.sciaf.2023.e01638

Bruscato, L. T., Freitas, E. P., & Heimfarth, T. (2016). Self-Correcting Time Synchronization Support for Wireless Sensor Networks Targeting Applications on Internet of Things. *IFAC-PapersOnLine*, *49*(30), 355–360. https://doi.org/10.1016/j.ifacol.2016.11.161

Caya, M. V., Cosindad, M. U., Marcelo, N. I., Santos, J. N. M., & Torres, J. L. (2019). Design and Implementation of an Intravenous Infusion Control and Monitoring System. *2019 IEEE International Conference on Consumer Electronics - Asia, ICCE-Asia 2019*, *2*, 68–72. https://doi.org/10.1109/ICCE-Asia46551.2019.8941599

Chen, F. G., Wang, J. Y., Chen, S., Tu, S. C., & Chen, K. Y. (2015). A hang-and-play intravenous infusion monitoring system. *Proceedings - 3rd International Conference on Applied Computing and Information Technology and 2nd International Conference on Computational Science and Intelligence, ACIT-CSI 2015*, 278–281. https://doi.org/10.1109/ACIT-CSI.2015.57

Chiradeja, P., & Yoomak, S. (2023). Development of public lighting system with smart lighting control systems and internet of thing (IoT) technologies for smart city. *Energy Reports*, *10*(March), 3355–3372. https://doi.org/10.1016/j.egyr.2023.10.027

Choudhury, S., Kuchhal, P., Singh, R., & Anita. (2015). ZigBee and bluetooth network based sensory data acquisition system. *Procedia Computer Science*, *48*(C), 367–372. https://doi.org/10.1016/j.procs.2015.04.195

Czerniel, J., Gostyńska, A., Jańczak, J., & Stawny, M. (2023). A critical review of the novelties in the development of intravenous nanoemulsions. *European Journal of Pharmaceutics and Biopharmaceutics*, *191*(July), 36–56. https://doi.org/10.1016/j.ejpb.2023.08.009

Fajrin, H. R., Ramdini, B. M., & Syaifudin, A. (2022). The Wireless-Based Monitoring Tool of the Volume and Rate of Infusion Drip. *AIP Conference Proceedings*, *2499*(November). https://doi.org/10.1063/5.0104942

Gabriel, K., Hovater, K., Gao, H., de la Cruz, D., Calkins, K. L., & Neu, J. (2023). Monitoring and management of hypertriglyceridemia in extremely low birth weight neonates receiving intravenous lipid emulsions: A national survey. *Early Human Development*, *186*(October), 105872. https://doi.org/10.1016/j.earlhumdev.2023.105872

Gawronska, J., Koyanagi, A., López Sánchez, G. F., Veronese, N., Ilie, P. C., Carrie, A., Smith, L., & Soysal, P. (2023). The Prevalence and Indications of Intravenous Rehydration Therapy in Hospital Settings: A Systematic Review. *Epidemiologia*, *4*(1), 18–32. https://doi.org/10.3390/epidemiologia4010002

Giaquinto, N., Scarpetta, M., Spadavecchia, M., & Andria, G. (2021). Deep learning-based computer vision for real-time intravenous drip infusion monitoring. *IEEE Sensors Journal*, *21*(13), 14148–14154. https://doi.org/10.1109/JSEN.2020.3039009

Hardi, E., Veigt, M., Koerdt, M., Herrmann, A. S., & Freitag, M. (2020). Monitoring of the vacuum infusion process by integrated RFID transponder. *Procedia Manufacturing*, *52*(2019), 20–25. https://doi.org/10.1016/j.promfg.2020.11.005

Jianwen, C., & Han, Z. (2011). Design of intravenous infusion monitoring and alarm system based on wireless communication technology. *2011 IEEE International Conference on Mechatronics and Automation, ICMA 2011*, 130–134. https://doi.org/10.1109/ICMA.2011.5985644

Kroeger, N., Badbaran, A., Holler, E., Hahn, J., Kobbe, G., Bornhauser, M., Reiter, A., Zabelina, T., Zander, A., & Fehse, B. (2006). Highly Sensitive Real-Time PCR of V617F-JAK2-Mutation To Monitor Minimal Residual Disease and Guide Donor Lymphocte Infusion after Allogeneic Stem Cell Transplantation in Patients with Myelofibrosis. *Blood*, *108*(11), 669–669. https://doi.org/10.1182/blood.v108.11.669.669

Kvalsund, A. S., & Winkler, D. (2023). Development of an Arduino-based, open-control interface for hardware in the loop applications. *HardwareX*, *16*(October), e00488. https://doi.org/10.1016/j.ohx.2023.e00488

Laukkanen, A. M., Horáček, J., & Radolf, V. (2021). Buzzer versus water resistance phonation used in voice therapy. Results obtained with physical modeling. *Biomedical Signal Processing and Control*, *66*. https://doi.org/10.1016/j.bspc.2021.102417

Ligęza, P. (2022). Method of testing fast-changing and pulsating flows by means of a hot-wire anemometer with simultaneous measurement of voltage and current of the sensor. *Measurement: Journal of the International Measurement Confederation*, *187*(May 2021). https://doi.org/10.1016/j.measurement.2021.110291

Lu, D., & Mao, W. (2023). Efficacy and safety of intravenous combined with aerosolised polymyxin versus intravenous polymyxin alone in the treatment of multidrug-resistant gram-negative bacterial pneumonia: A systematic review and meta-analysis. *Heliyon*, *9*(5), e15774. https://doi.org/10.1016/j.heliyon.2023.e15774

Majid, S. H., Yusro, M., Yuliatmojo, P., & Siregar, K. N. (2021). Web-based intravenous fluid monitoring. *IOP Conference Series: Materials Science and Engineering*, *1098*(4), 042085. https://doi.org/10.1088/1757-899x/1098/4/042085

Mantenuto, P., De Marcellis, A., & Ferri, G. (2012). On the sensitivity characteristics in novel automatic wheatstone bridge-based interfaces. *Procedia Engineering*, *47*, 261–264. https://doi.org/10.1016/j.proeng.2012.09.133

Martinsen, M. R., Davey, N. G., Bell, R. J., Krogh, E. T., Gill, C. G., Mikkelsen, Ø., & Schmid, R. (2020). A field portable membrane introduction mass spectrometer with in-line standard infusion and sample heat exchanger for real-time monitoring of volatile organic compounds in aqueous samples. *Environmental Chemistry and Ecotoxicology*, *2*, 168–174. https://doi.org/10.1016/j.enceco.2020.09.003

Naeim, M. K. M., Chung, G. C., Lee, I. E., Tiang, J. J., & Tan, S. F. (2023). A Mobile IoT-based Elderly Monitoring System for Senior Safety. *International Journal of Technology*, *14*(6), 1185–1195. https://doi.org/10.14716/ijtech.v14i6.6634

Noel-Weiss, J., Woodend, A. K., Peterson, W. E., Gibb, W., & Groll, D. L. (2011). An observational study of associations among maternal fluids during parturition, neonatal output, and breastfed newborn weight loss. *International Breastfeeding Journal*, *6*, 2–11. https://doi.org/10.1186/1746-4358-6-9

Polderman, J. A. W., Ma, X. L., Eshuis, W. J., Hollmann, M. W., Devries, J. H., Preckel, B., & Hermanides, J. (2017). Efficacy of continuous intravenous glucose monitoring in perioperative glycaemic control: A randomized controlled study. *British Journal of Anaesthesia*, *118*(2), 264–266. https://doi.org/10.1093/bja/aew455

R, N., & Susanti, D. (2019). Pengembangan Bahan Ajar Trigonometri Berbasis Literasi Matematika. *Jurnal Borneo Saintek*, *2*(1), 37–45. https://doi.org/10.35334/borneo_saintek.v2i1.633

Roohani, I., Entezari, A., & Zreiqat, H. (2023). Liquid crystal display technique (LCD) for high resolution 3D printing of triply periodic minimal surface lattices bioceramics. *Additive Manufacturing*, *74*(July), 103720. https://doi.org/10.1016/j.addma.2023.103720

Santos, C. C., Costa, M. J., Forte, P., & Marinho, D. A. (2023). A comparison of load cell and pressure sensors to measure in-water force in young competitive swimmers. *Journal of Biomechanics*, *160*(September). https://doi.org/10.1016/j.jbiomech.2023.111815

Sifa Fauziyyah, A., & Yohandri. (2020). Design of automatic infusion monitoring system based on Arduino. *Journal of Physics: Conference Series*, *1528*(1). https://doi.org/10.1088/1742-6596/1528/1/012025

Smith, R., Rolfe, A., Cameron, C., Shaw, G. M., Chase, J. G., & Pretty, C. G. (2022). Low cost circulatory pressure acquisition and fluid infusion rate measurement system for clinical research. *HardwareX*, *11*, e00318. https://doi.org/10.1016/j.ohx.2022.e00318

Swedarma, K. E., Saputra, I. K., Tri Mulyani Hastuti, F., & Irfan Mudhoep, D. (2023). Infusion Fluid Monitoring System Using Arduino Microcontroller and Internet of Think (IoT) to Increase Work Efficiency of Nurses in Hospital. *Nursing and Health Sciences Journal (NHSJ)*, *3*(2), 175–183. https://doi.org/10.53713/nhsj.v3i2.204

Talić, A., Ćerimović, S., Beigelbeck, R., Kohl, F., Jachimowicz, A., & Keplinger, F. (2009). Novel Thermal Flow Sensors Based on a Wheatstone Bridge Read-out. *Procedia Chemistry*, *1*(1), 136–139. https://doi.org/10.1016/j.proche.2009.07.034

Venkatesh, K., Alagundagi, S. S., Garg, V., Pasala, K., Karia, D., & Arora, M. (2022). DripOMeter: An open-source opto-electronic system for intravenous (IV) infusion monitoring. *HardwareX*, *12*, e00345. https://doi.org/10.1016/j.ohx.2022.e00345

Wang, S., & Jiang, B. (2018). Design of wireless infusion monitor based on Bluetooth 4.0. *Proceedings of the 13th IEEE Conference on Industrial Electronics and Applications, ICIEA 2018*, 750–754. https://doi.org/10.1109/ICIEA.2018.8397813

Xinling, W. (2008). Design of medical infusion monitor and protection system based on wireless communication technology. *Proceedings - 2008 2nd International Symposium on Intelligent Information Technology Application, IITA 2008*, *2*, 755–759. https://doi.org/10.1109/IITA.2008.47

Zhang, Y., Zhang, S., Ji, Y., & Wu, G. (2010). Intravenous infusion monitoring system based on WSN. *IET Conference Publications*, *2010*(575 CP), 38–42. https://doi.org/10.1049/cp.2010.1024