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Infusion bottle monitoring system based on IoT

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Abstract

In the field of healthcare, the intravenous fluid infusion process has become a crucial method in patient recovery. However, monitoring and replacing infusions pose challenges for hospitals due to limited medical staff and time constraints. Currently, infusion control is still manual, leading to risks such as delayed handling when the infusion is depleted and the potential for blood clot formation. Therefore, the use of technology is essential to address these issues. This research aims to design and create a monitoring and alert device for real-time patient infusion bottle conditions based on the Internet of Things (IoT) related to weight, utilizing a website. The ON/OFF method serves as the primary framework for designing and implementing the IoT-based patient infusion bottle monitoring system. The research results include an infusion pole equipped with Load cell sensors and a website application capable of monitoring the patient's infusion bottle conditions in the nurse's room. The conclusion drawn from the study is a comparison of sensors with digital scales, showing a percentage error of 0.11% for Load cell A and 0.14% for Load cell B. The average measurement tolerance at different infusion flow rates exhibits variation. At slow infusion rates, the average tolerance for infusion A is -0.66%, while for infusion B, it is -0.06%. At moderate infusion rates, the average tolerance for infusion A is -0.97%, and for infusion B, it is -0.66%. At fast infusion rates, the average tolerance for infusion A is -0.13%, and for infusion B, it is -0.04%.

Keywords

Infusion bottle, Monitoring system, IoT

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Introduction

In the field of health, intravenous fluid administration through the infusion process has become a crucial method in caring for and recovering patients. Intravenous infusion fluids are used to replace the loss of fluids or nutrients in the patient's body by using a needle injected into the vein. Despite the importance of this infusion process, monitoring and replacing infusions are among the challenges frequently faced by hospitals. This is due to the high demands for patient care and the limited availability of medical personnel. Sometimes, a patient's infusion may run out without immediate

replacement due to the constraints of nurses who can continuously monitor patients for 24 hours. In such situations, patients may need to use a call button to request nurse assistance and provide information about the need for infusion replacement. However, this is not always effective because nurses are not always near the patient and need to periodically check the infusion [1]–[4]. In the current medical world, infusion control is still manually performed. This manual method takes a considerable amount of time, especially if nurses need to visit all patient rooms. Besides the time consumption, there is also a risk if patient care is delayed when the infusion is almost depleted. If a patient's infusion bottle is empty but still attached to the body, the pressure on the infusion set becomes unstable. This condition can pose a risk of blood clot formation in the infusion tube, which can then be sucked back into the bloodstream. Blood clots carried throughout the body can block blood capillaries in the lungs, known as embolism. Furthermore, this condition can lead to other complications such as the occurrence of blood clots trapped in the infusion tube, hindering the flow of infusion fluid [1], [5]. In addressing the above issues, the use of technology becomes crucial to reduce such unwanted incidents. Therefore, this research aims to develop a system that can monitor the real-time condition of a patient's infusion bottle based on the Internet of Things (IoT). Through the use of IoT technology, it is expected that this system can assist medical personnel in effectively monitoring patient infusions and provide alerts when immediate action is needed, such as when the infusion fluid is nearly depleted.

Method

Figure 1 illustrates the procedural steps in the research method. First, it begins with a literature review to obtain information about the materials used. Next, the system design is carried out, encompassing various processes such as sensor calibration, internet connection, sending weight data to the server, storing data in the database, weight condition readings, and displaying data on the user interface. The device assembly process is followed by system testing to ensure optimal performance. If the device proves to function well, the next steps involve data analysis followed by the compilation of the research report. Conversely, if challenges arise during testing, it will revert to the device assembly stage before progressing to the next phase.

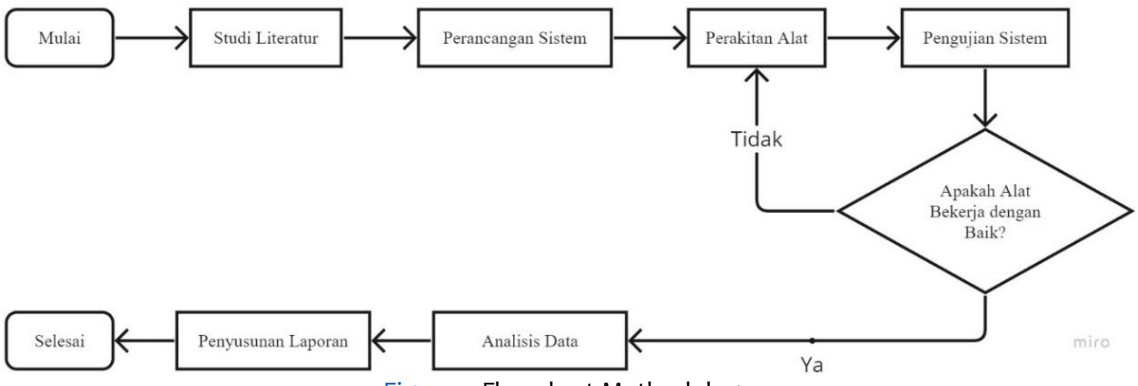

Figure 1. Flowchart Methodology

Hardware design

In the first part of the above block diagram is the input section, consisting of two load cell sensors tasked with measuring the load or weight on the infusion bottle. Data obtained from the load cell sensors is then forwarded to the HX-711 module, which serves as a link between the load cell sensors and the microcontroller. After going through the Input process, the data then enters the processing section, which includes the NodeMCU ESP8266. The NodeMCU ESP8266 acts as the brain of the system, receiving data from the HX-711 and processing the data according to the predefined algorithm. Additionally, the NodeMCU ESP8266 is responsible for connecting the system to the WiFi network, allowing the data to be sent to the server or displayed on a website. Finally, the results of this process are displayed through the output section. The output section consists of an LCD, used as a local display to show the measurement results from the sensor, specifically the weight of the infusion bottle. Furthermore, the data collected or received by the NodeMCU ESP8266 can also be accessed through the website (Figure 2).

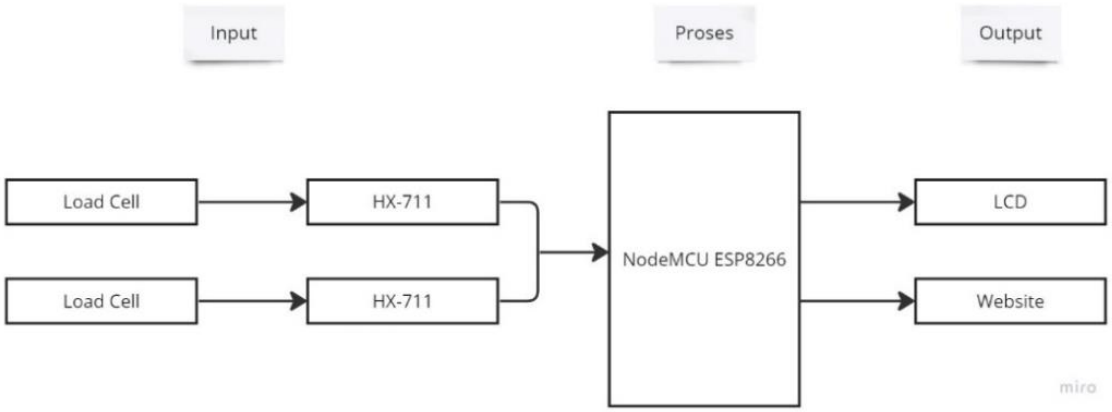

Figure 2. Block Diagram of Infusion Bottle Monitoring System

Software design

The software design will utilize the Arduino IDE for programming the NodeMCU ESP8266 and Visual Studio Code for developing the website application. The Arduino IDE software is employed to manage the logic and functionality of the system in this research, while Visual Studio Code is used to program the website application that serves as the user interface for the IoT-based patient infusion bottle monitoring system.

Results and Discussion

Results and discussions encompass the outcomes of both hardware and software design, testing results involving the measurement of infusion drip rates, notifications through the website, and an analysis of the weight measurement results of the infusion.

Results of hardware design

The circuit components are assembled using a PCB board with holes for arranging and connecting the components through soldering with solder and soldering tin (Figure 3).

On the PCB board, there are female pin headers used to place the NodeMCU ESP8266, HX711 module, and pin connections for the LCD. Jumper cables with a length of 20 cm are used to connect the current from NodeMCU ESP8266 to other components. A ribbon cable with an XH 4 Pin Connector is installed to connect with the load cell. This circuit can use power from a Rechargeable Battery 18650. With the Rechargeable Battery 18650, the prototype of this infusion bottle monitoring device can move freely.

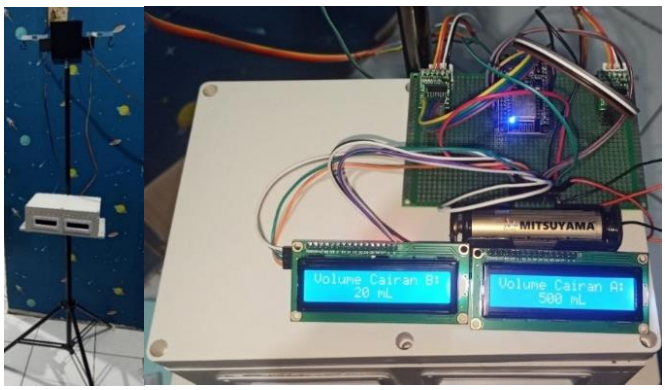

Figure 3. Results of Frame Tool Manufacturing (left) and Results of Electrical Component Wiring (right)

Results of software design

In Figure 4, the login page interface is displayed on the designed website application. The purpose of this login page is to ensure that only authorized users, such as nurses or administrators, can access the full features of the website. During the login process, users will be prompted to enter valid account data, such as a username and password. After correctly filling in the account information, the system will verify the authenticity of the data. If the entered data matches what is registered in the database, the user will be redirected to a page that corresponds to their role.

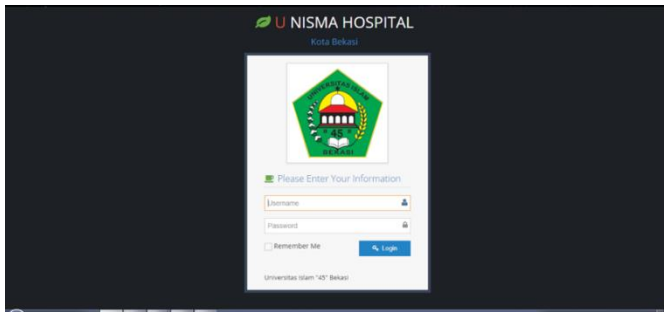

Figure 4. Website Login Display

If the user logging in is identified as a nurse or admin, they will be directed to the admin page that provides full access to edit, add, or delete data in the system. However, if the user logging in is detected as a visitor or patient, they will be directed to a special visitor or patient page. This allows nurses or admins to manage information easily and efficiently.

Test results for infusion drop flow rate measurements

The measurement data of infusion weight based on droplet speed can be seen in the following Table 1, Table 2 and Table 3.

Table 1. Weight Measurement Data Based on Slow Infusion Flow Rate

Time	Infusion A (%)			Tolerance	Infusion B (%)			Tolerance
	Test 1	Test 2	Test3	(%)	Test 1	Test2	Test 3	(%)
0	100	100	100	0	100	100	100	0
10	97.2	97	97	-0.21	98.8	98.6	98.6	-0.20
20	94.2	94.2	94	0	95.6	95.4	95.4	-0.21
30	90.8	91	90.8	0.22	92.4	92.4	92.6	0
40	87.6	87.4	87.6	-0.23	89.2	89.4	89.2	0.22
50	84.4	84.2	84.2	-0.24	86.4	86.2	86.6	-0.23
60	81.2	81.2	81.4	0	83.4	83.4	83.2	0
Average Tolerance				**-0.66**	**Average Tolerance**			**-0.06**

Table 2. Weight Measurement Data Based on Medium Infusion Flow Rate

Time	Infusion A (%)			Tolerance	Infusion B (%)			Tolerance
	Test 1	Test 2	Test3	(%)	Test 1	Test 2	Test 3	(%)
0	100	100	100	0	100	100	100	0
10	78.2	78.0	78.2	-0.26	79.8	79.6	79.8	-0.25
20	56.4	56.4	56.2	0	58.0	58.2	58.2	0.34
30	34.6	34.4	34.8	-0.58	36.2	36.0	36.2	-0.55
40	12.8	13.0	12.8	0.16	14.4	14.4	14.2	0
50	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
Average Tolerance				**-0.97**	**Average Tolerance**			**-0.66**

Table 3. Weight Measurement Data Based on Fast Infusion Flow Rate

Time	Infusion A (%)			Tolerance	Infusion B (%)			Tolerance
	Test 1	Test 2	Test 3	(%)	Test 1	Test 2	Test3	(%)
0	100	100	100	0	100	100	100	0
10	65.8	65.6	65.8	-0.30	67.4	67.2	67.4	-0.30
20	31.6	31.4	31.6	-0.63	33.2	33.2	33.2	0
30	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0
Average Tolerance				**–0.13**	**Average Tolerance**			**-0.04**

The formula applied to calculate the tolerance values in the above table is as follows [4].

$$\text{Tolerance} = \frac{Y-X}{X} \times 100\%$$

Where, X = Value of Test 2 and Y = Value of Test 1

To calculate the average tolerance value in the table above, the following formula is used.

$$\text{Average Tolerance} = (\Sigma\text{Tolerance}) / \text{number of data}$$

Where, ΣTolerance = total sum of tolerance values and Number of Data = total number of tolerance data.

The measurement of infusion flow rate is conducted in several tests (slow, medium, fast). In the first test, the weight of infusions A and B is 500 ml or 100% at 0 minutes. After 10 minutes, the weight of infusion A becomes 486 ml (97.2% of the initial), while infusion B becomes 494 ml (98.8% of the initial). The test continues for 60 minutes, where the weight of infusion A remains 406 ml (81.2% of the initial total), while infusion

B remains 417 ml (83.4% of the initial total). The average tolerance after three trials is -0.66% for infusion A and -0.06% for infusion B. At a medium infusion flow rate, the weight of infusions A and B is 500 ml or 100% at 0 minutes. After 10 minutes, the weight of infusion A becomes 391 ml (78.2% of the initial), while infusion B becomes 399 ml (79.8% of the initial). At minute 60, the weight of infusions A and B is empty, remaining 0 ml (0% of the initial total). The average tolerance after three trials is -0.97% for infusion A and -0.66% for infusion B. At a fast infusion flow rate, the weight of infusions A and B is 500 ml or 100% at 0 minutes. After 10 minutes, the weight of infusion A becomes 329 ml (65.8% of the initial), while infusion B becomes 337 ml (67.4% of the initial). At minute 60, the weight of infusions A and B is empty, remaining 0 ml (0% of the initial total). The average tolerance after three trials is –0.13% for infusion A and -0.04% for infusion B.

Test results for website notifications

Figure 5. Website Notification Measurement Data <101 and >54

Figure 6. Website Notification Measurement Data <=54 and >=3

Figure 7. Website Notification Measurement Data <=2

Testing notifications on the website is conducted to ensure that the system can send notifications accurately at the specified times (Figure 5, 6 and 7). This is crucial in providing information to nurses or admins about the status of the infusion bottle, weight changes, or other important events related to the infusion bottle monitoring.

Analysis of test results on infusion weight measurements

The data obtained can be seen in Table 4 and Table 5 for the measurement results of the weight of Infusion A and Infusion B. The formula applied to calculate the error values in the table above is as follows [3].

$$\text{Error} = \frac{X-Y}{Y} \times 100\%$$

Where, X = Load cell sensor measurement result and Y = Measurement scale value

In both tables, it is evident that the Load cell sensors on Infusion A and Infusion B exhibit a relatively high level of measurement accuracy. The measurement data from the Load cell sensors has achieved an accuracy level that is nearly comparable to a scale with an accuracy of 1 gram and a capacity of 10 kilograms. The average error values for Infusion A and Infusion B are 0.11% and 0.14%, respectively. The comparison between the measurement results from the Load cell sensors and the scale indicates insignificant differences, with a small margin between the measured values.

Table 4. Measurement Data of Infusion A Weight

Scale (ml)	Digital Scale (ml)	Infusion B (ml)	Difference (ml)	Error (%)
500	500	500	0	0
450	450	451	1	0.2
400	400	400	0	0
350	350	350	0	0
300	300	301	1	0.3
250	250	250	0	0
200	200	201	1	0.5
150	150	150	0	0
100	100	100	0	0
	Rate		**0.33**	**0.11**

Table 5. Measurement Data of Infusion B Weight

Scale (ml)	Digital Scale (ml)	Infusion B (ml)	Difference (ml)	Error (%)
500	500	501	1	0.2
450	450	451	1	0.2
400	400	400	0	0
350	350	351	1	0.3
300	300	300	0	0
250	250	250	0	0
200	200	200	0	0
150	150	151	1	0.6
100	100	100	0	0
	Rate		**0.44**	**0.14**

Conclusion

Based on the conducted tests, the following conclusions have been drawn. The patient infusion bottle monitoring system has been successfully designed and created, capable of connecting to the Internet of Things (IoT) on a website. The comparison results between the sensor and the digital scale show a percentage error of 0.11% on Load cell A and 0.14% on Load cell B. In the tests for slow infusion flow rate, the average tolerance for Infusion A is -0.66%, while for Infusion B, it is -0.06%. At a medium infusion flow rate,

the average tolerance for Infusion A is -0.97%, and for Infusion B, it is -0.66%. At a fast infusion flow rate, the average tolerance for Infusion A is –0.13%, and for Infusion B, it is -0.04%.The sensor has successfully transmitted measurement data to the website, and notifications can be displayed accurately.

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