IoT-based infusion monitoring system with blood detection and automatic flow rate control

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ABSTRACT

The advancement of technology has driven innovation in health monitoring systems based on the Internet of Things (IoT), offering convenience and efficiency in patient condition monitoring. This study develops an IoT-based system for monitoring the volume of NaCl (saline) infusion and detecting blood reflux in the infusion tubing to enhance patient care effectiveness. The system utilizes a Wemos D1 Mini microcontroller connected to the Blynk application, enabling medical personnel to monitor and control the infusion process in real-time via smartphone. The system is equipped with a Load Cell sensor to measure infusion volume, an LDR sensor to detect blood reflux based on changes in light intensity, and a photodiode sensor to calculate infusion drip rate. Additionally, a servo motor is used to regulate the infusion flow rate by adjusting the pressure on the tubing. All collected data is transmitted in real-time to the IoT platform, allowing healthcare workers to perform continuous monitoring without repetitive manual checks. Testing results show that the system accurately monitors infusion volume, detects blood reflux, and controls drip rate. The implementation of this device improves monitoring efficiency, accelerates response to changes in patient condition, and reduces the potential for human error. The success of this system contributes to the advancement of healthcare technology, particularly in hospital patient monitoring and intensive care settings.

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1. INTRODUCTION

Technological developments in the medical field have led to the birth of increasingly sophisticated and efficient medical devices, including infusion monitoring systems. An IV is an important medical device used to replace body fluids, balance electrolytes, and deliver medication directly into the blood vessels. However, infusion monitoring is currently generally still carried out manually by medical personnel, which requires time and energy and carries the risk of delays in treatment [1].

An unmonitored infusion that runs out, changes in the drip, or backflow of blood due to a blockage can be dangerous for the patient if not treated immediately. Even though there are infusion monitoring systems, most of them are still local and not supported by IoT technology, so remote monitoring is not yet effective [2]. Each nurse will replace the patient's IV fluids when the fluids run out. Often the patient's IV drip runs out and the IV fluid has not been replaced, because the number of nurses and patients is not balanced in monitoring the patient for 24 hours. Sometimes the patient has to press a button to call the nurse to provide information to change the infusion [3]. This is very important because delays in replacing the infusion or differences in the speed of infusion flow in patients can have fatal consequences for the patient being treated [4].

Intravenous fluid monitoring is generally still carried out traditionally by nurses who have to check the condition of each patient one by one for 24 hours. This method often leads to negligence, such as errors in tube installation, which can trigger the formation of blood clots (blood cloth) [5]. This can affect the smooth flow of fluids if not treated immediately. Blood clots can enter blood vessels and cause blockage or death, so immediate action is needed [6]. Blood clots circulate throughout the body and can block the capillaries of the lungs, causing a pulmonary embolism. In this case, the injection site needs to be relocated and another vein created. This does not rule out the possibility of various complications which are much more dangerous if done incorrectly [7]. Therefore, a system is needed that can monitor and provide notifications regarding the patient's infusion condition remotely, such as the volume of infusion fluid, the number of infusion drops per minute, and the blood rising in the infusion tube so that it can minimize nurse negligence in monitoring the patient's infusion [8].

Along with advances in medical science and technology, medical devices such as infusions have also developed. Infusion functions to provide fluids or medication accurately to patients, so it requires proper supervision [9]. Currently, a system has been developed to monitor infusions by utilizing weight sensors to measure infusion capacity. Each device is connected to a website application that is connected to the internet network. With this technology, it is hoped that nurses can monitor each patient's infusion information via computer from the nurse's room [10]. However, this system still has several weaknesses, one of which is that the display on the website is not yet portable and is not yet able to provide direct notification to nurses when the patient's infusion is almost empty [11]. Internet of Things (IoT) technology was developed with the aim of expanding the capabilities of internet connections so that they can operate in real-time. As a global infrastructure network, IoT enables integration between hardware and software through data exchange and communication, thereby facilitating various human activities [12]. Infusion monitoring is still done manually, which is time-consuming and risky if there is a delay. Therefore, it is necessary to utilize technology such as the Internet of Things (IoT) to design an automatic and real-time infusion monitoring system, in order to increase efficiency and patient safety [13].

Through the application of IoT technology, IoT-based infusion fluid monitoring uses a website connected to the internet network. With this technology, it is hoped that nurses can monitor patient infusion information via computer or even smartphone from the nurse's room. [14]. The infusion monitoring system can be done automatically and in real-time remotely. Therefore, this study developed a tool for monitoring the volume of NaCl fluid (infusion) and detecting rising blood in the infusion tube using a Wemos D1 Mini microcontroller connected to the Blynk application..

2. METHOD

The design begins with the creation of a block diagram. A block diagram is a basic description of the system to be designed in the form of a diagram connected by lines as indicators between blocks [15]. Each part of the system block in the block diagram has its own function. The I/O block diagram of the device can be seen in Figure 1.

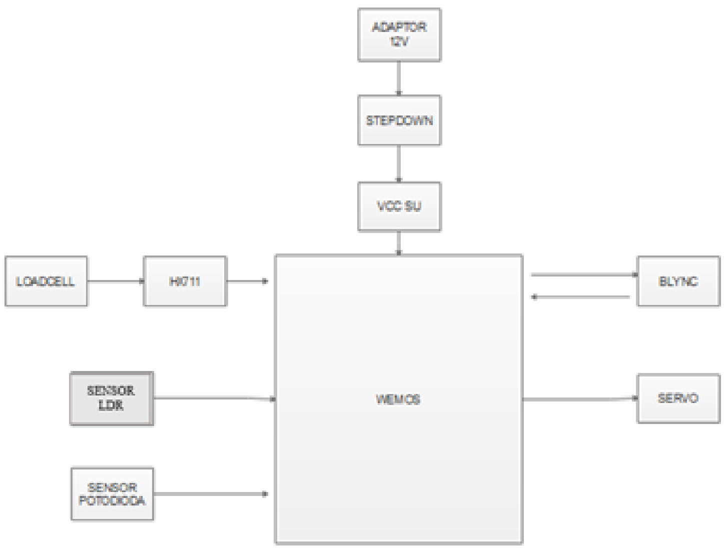

Figure 1. Diagram block of proposed system

The system block diagram in Figure 1 depicts the system structure which consists of several components with different functions, this system consists of several main components. The 12 V adapter functions to convert AC voltage from the power source to 12 V DC voltage. The load cell sensor functions to measure the weight of the infusion fluid. The Photodiode sensor detects light from the infusion fluid to read the infusion drips. The LDR (Light Dependent Resistor) sensor detects the presence of blood based on its blood level value. The Wemos D1 Mini processes data to read electrical signals from load cells and LDR sensors and sends them to a computer or other device. Blynk is a software platform that allows you to create Internet of Things (IoT) applications without writing code. With certain symbols that describe the process sequence in detail and the relationship between one process and another process in a program, it is called a Flowchart. The following is a flowchart of the proposed system.

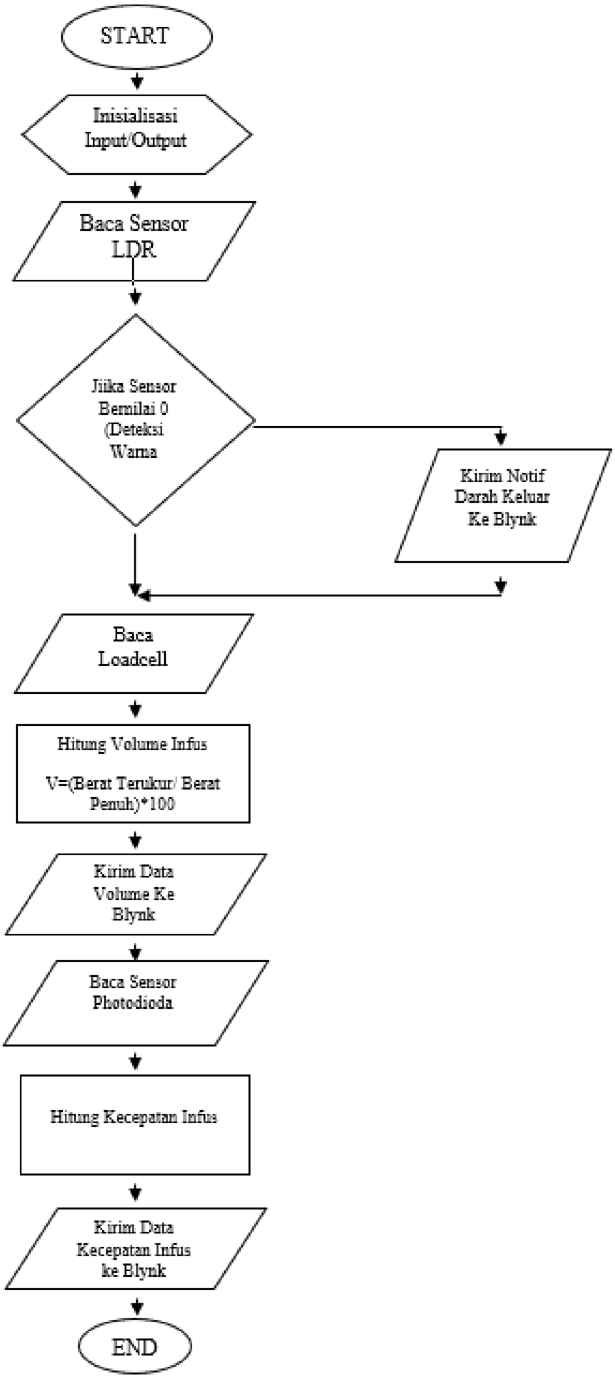

Figure 2. Flowchart of proposed system

Figure 2 provides a detailed explanation of the system workflow with a flowchart as a visual representation. Flowcharts help analysts and programmers to break down problems into smaller segments. Start, which means the beginning of the flowchart, describes the process of reading data from several sensors, calculating volume based on weight, and sending data to the Blynk platform for further monitoring or analysis. This workflow ensures that all relevant sensor data is processed and communicated correctly.

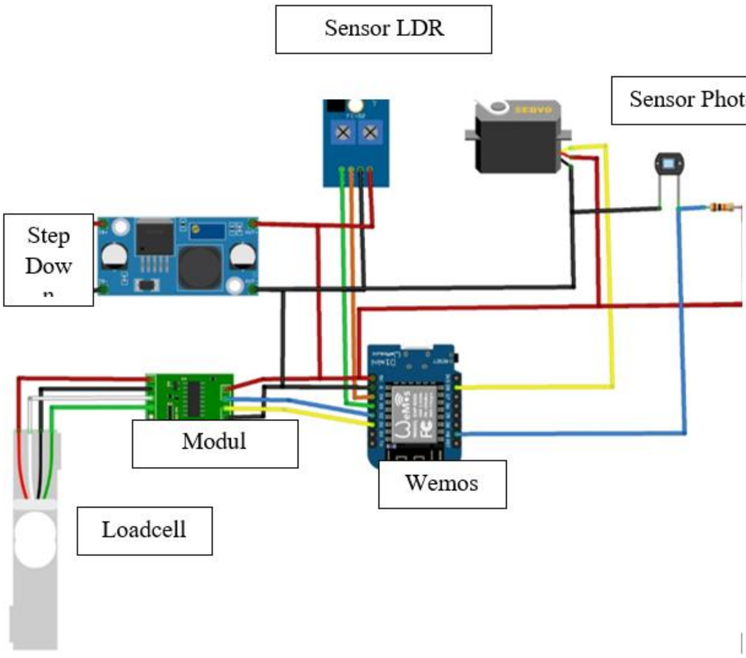

Figure 3. Overall series of tools

Figure 3 shows a detailed circuit schematic showing the relationships between the components used in the system. This scheme is designed in accordance with the description in the block diagram which also reflects the relationship between components.

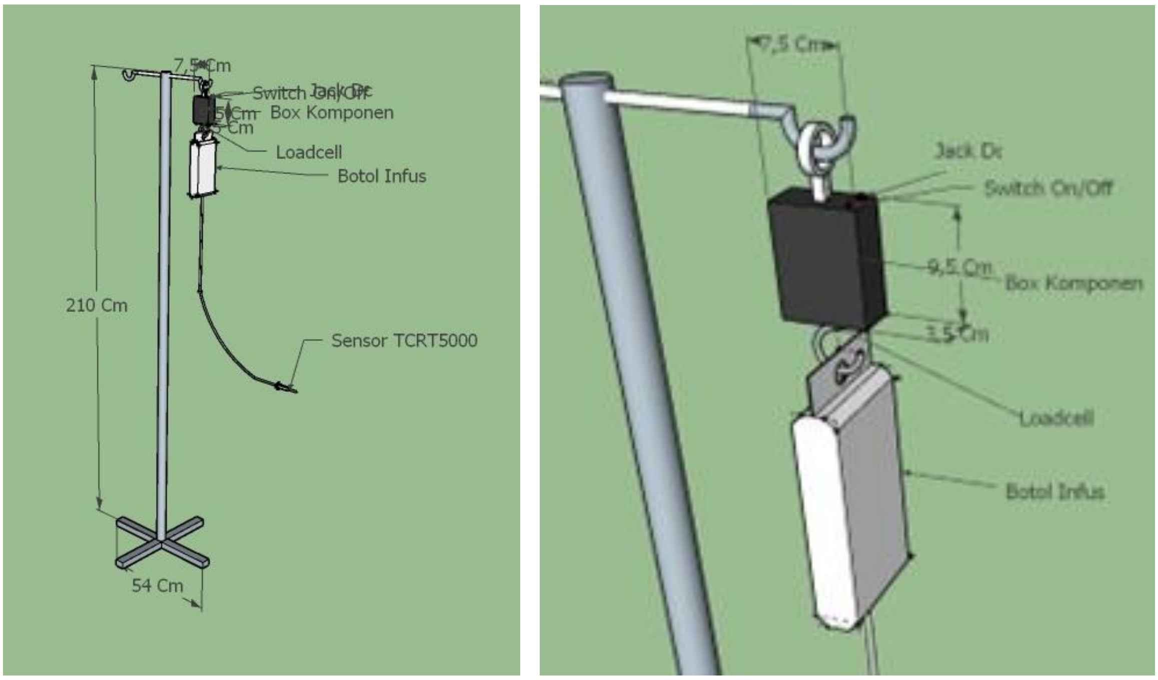

Figure 4. Overall design of the tool

3. RESULTS AND DISCUSSION

After completing the assembly of the tool, the next step is testing. Figure 5 shows the tool testing process. Figure 5 shows the results of voltage measurements from the adapter, where the measured voltage is 5.39 volts. Based on these measurement results, it can be concluded that the adapter is in good condition.

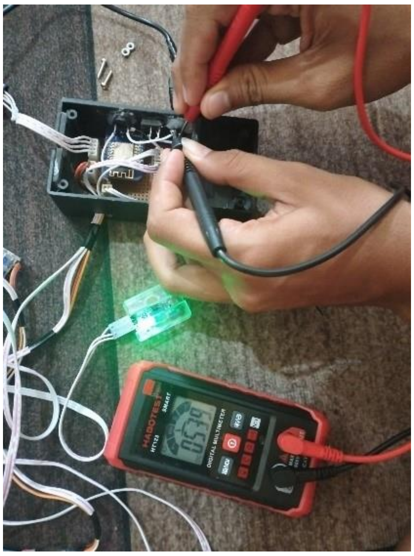

Figure 5. Hardware testing

Next, the LDR sensor module was tested, which is used to detect blood rising into the IV. The LDR sensor is used because the LDR sensor can read the brightness of light in the form of analog data. The light on the IV tube with blood and without blood has different light intensity. From the light intensity, the threshold can be taken, namely when the analog value of the light sensor is >500, then blood is detected. The test results can be seen in the experimental data in Figure 6.

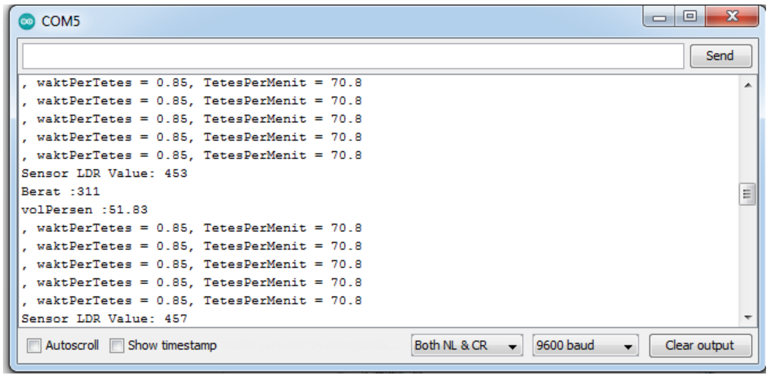

Figure 6. LDR Sensor data when there is no blood

In Figure 6, you can see the analog value of the LDR sensor is 453 when there is no blood in the IV line, there is no information that blood has been detected, because the program will detect blood rising when the analog data of the LDR sensor is >600. Table 1 shows the analog value data from the LDR sensor taken randomly from 112 to 537, indicating that the infusion status is normal because the program did not detect any blood rising into the infusion tube.

Table 1. Analog values of the LDR sensor when there is no blood

No.	LDR Data	Infusion status
1.	112	Normal
2.	212-215	Normal
3.	316-326	Normal
4.	416-417	Normal
5.	517-537	Normal

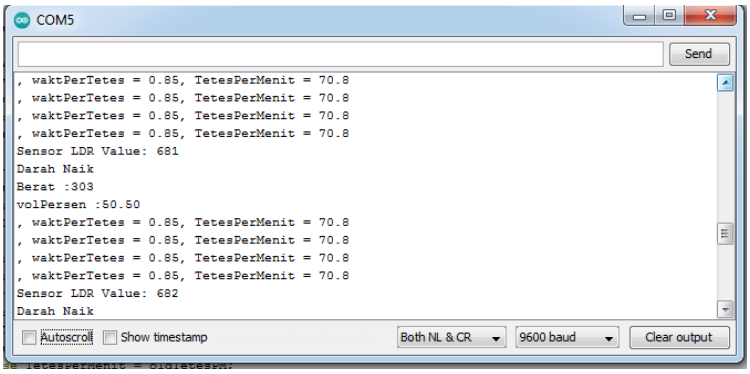

Figure 7. LDR sensor data when there is blood

In Figure 7, you can see the analog value of the LDR sensor is 681 when there is blood in the IV line, so there will be a message that the blood level is rising, because the program will detect rising blood when the analog data of the LDR sensor is >600. Table 2 describes the analog value data from the LDR sensor taken randomly from 607 to 1002 that the blood infusion status increased because the program detected blood rising into the infusion tube.

Table 2. Analog values of the LDR sensor when there is blood

No.	LDR Data	Infusion status
1.	607-637	Blood Pressure
2.	699-702	Blood Pressure
3.	806-818	Blood Pressure
4.	818-938	Blood Pressure
5.	999-1002	Blood Pressure

To detect the speed of infusion drops on the device, the author uses a photodiode sensor where the photodiode can detect objects in front of it, if there is an object detected by the photodiode. When there is no object in front of the sensor, the sensor output will be 0 (low) and if an object is detected in front of the sensor, the sensor output will be 1 (high), as can be seen in Figure 8(a).

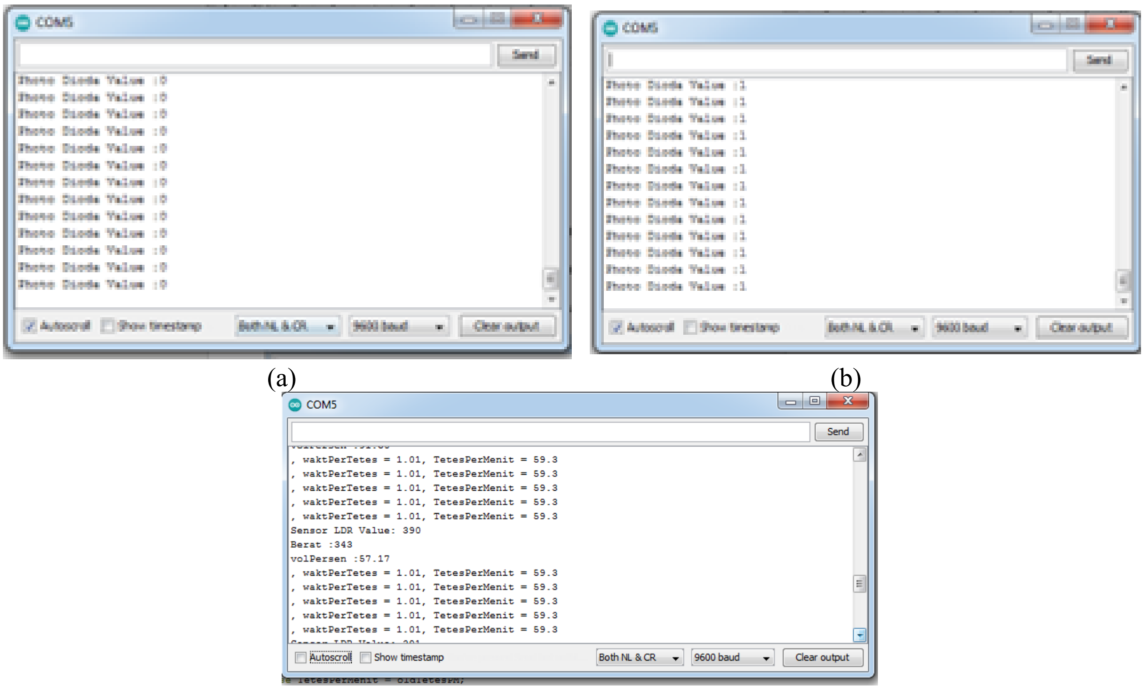

Figure 8. Testing the Infusion Sensor (Photodiode). a) Sensor output when no object is detected, b) Sensor output when no object is detected, c) Output calculation of infusion drops in a minute

It can be seen in Figure 8(a) that when there is no object in front of or passing the sensor, the sensor output is 0 (low), and Figure 8(b) shows that when there is an object in front of the photodiode sensor, the output is 1 (high). From the experiments carried out, it can be concluded that the photodiode sensor is in good condition. To be able to read the infusion rate, in our program we use an interrupt timer which functions to calculate the time interval between detecting the infusion fluid when it falls in seconds. To convert the number of infusion drops in one minute, use the formula Drops Per Minute = 60/infusion drop interval. The results of the drops per minute calculation calculated using a diode sensor and interrupt timer can be seen in Figure 8(c).

The load cell is used to calculate the weight of the infusion and then convert it into a percentage value using the formula Infusion Percentage Volume = Infusion Weight / 600 x 100 Grams. The value of 600 grams is the weight of the infusion in full condition. The results of the infusion volume measurements are described in Table 3.

Table 3. Measurement of infusion load based on percentage

No.	Infusion Percentage Volume	Infusion Fluid Mass
1.	100%	600gr
2.	75%	450gr
3.	52%	312gr
4.	26%	156gr
5.	2%	12gr

Next, the servo motor was tested. The servo motor is only set to 100-150 degrees. The larger the servo angle, the larger the infusion drops will be. If the servo angle is set to 100 degrees, the infusion drops will stop. In this test, the author measured the infusion drops based on the servo angle that was set. Table 4 is the data for patient 1 using a 20G needle and Table 5 is the data for patient 2 using a 22G needle.

Table 4. Infusion rate control Patient A needle size 20G

No.	Servo angle	Infusion Rate (Drops Per Minute)
1.	0	0
2.	10	0
3.	20	6
4.	30	15
5.	40	20
6.	50	25
7.	60	32
8.	70	39
9.	80	52
10.	90	55
11.	100	57
12.	110	60
13.	120	62

Table 5. Infusion rate control for Patient B, needle size 22G

No.	Sudut Servo	Infusion Rate (Drops Per Minute)
1.	0	0
2.	10	0
3.	20	4
4.	30	7
5.	40	12
6.	50	23
7.	60	49
8.	70	60
9.	80	63
10.	90	63
11.	100	65
12.	110	68
13.	120	69

Table 4 and Table 5 are the infusion speed control tests using servo which were carried out on both patients. From the tests that have been carried out, it can be concluded that the infusion speed can be controlled using an online application. The greater the servo angle, the faster the infusion drops will be. From the two table data, there is a slight difference in the infusion speed at the specified angle, this occurs because humans have different vein sizes and in this test the patient's needle size has a different size, so this difference in infusion speed occurs because of the size of the needle and vein in the patient.

In the tool created by the author, the Blynk platform is used to monitor and control infusion drops. In this Blynk application, you can see the infusion speed, infusion volume, infusion status and can control the infusion drop speed. The appearance of the Blynk application can be seen in Figure 9.

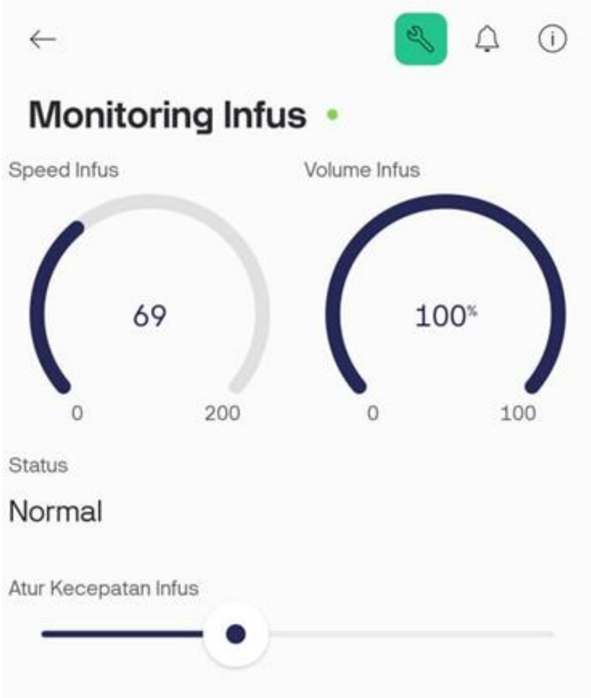

Figure 9. Infusion Monitoring Display in the Blynk Application

4. CONCLUSION

Based on the results of the tests that have been carried out, the development of infusion control monitoring technology and blood entry markers in the tube has been successfully carried out. Testing has proven that the designed system can control and monitor infusions and blood markers accurately and efficiently. Monitoring the volume of the infusion can use a load cell. From the measurement results, you can see what percentage of the remaining infusion volume is, this volume can be monitored on the display in the Blynk application. To find out if blood is rising in the IV line, you can use an LDR sensor which can read the light intensity. The light intensity on the line when there is blood and when there is no blood is different. Controlling the infusion drip speed can use a servo which functions to bend the infusion tube. The servo angle can be adjusted using the slider in the blynk application. From the tests that have been carried out, it can be concluded that the tool works according to the design..

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