Web-based intravenous fluid monitoring

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Abstract. Hospitals and community health centers in Indonesia still use conventional infusion devices to treat patients. Technological developments have made many medical devices automatically controlled. This study aimed to provide a web-based intravenous fluid monitoring using NodeMCU. The sensor consisted of a load cell sensor as a reader for the remaining infusion fluid, an optocoupler sensor as a blood detector, and a photodiode sensor to read the number of drops. In the event of dangerous situations such as an intravenous fluid running out, blood entering the intravenous line or the liquid is not dripping, the tool will give a warning through status LED, buzzer sound, and warning sounds on the web. This system has an error value of 3.12% for mass readings, 6.47% errors for droplet readings and 0% errors for blood detection. This system works by utilizing a Wi-Fi internet network. This system is expected to enable nurses, doctors, and patient’s families to monitor a patient's intravenous fluids in real-time conditions.

1. Introduction

Indonesia is the fourth most populous country in the world based on Worldometers 2019 with a total of 269 million people [1,2]. Based on data from the 2019 Legatum Prosperity Index, Indonesia ranks 97 out of 167 countries in the world in the health sector [3]. Health is a valuable asset for each individual. One of the problems in the health sector in Indonesia is that health human resources are still not optimal, both in number, type, quality, and distribution [4,5]. The limitations of health human resources have an impact on hospital services, where there are patients who have not received maximum treatment, especially in handling inpatients.

At present, it is estimated that about 90% of patients in hospitals use infusion pumps to administer infusion drugs [6]. Generally, intravenous fluids are the most commonly used inpatient drugs in hospitals throughout the world [7]. Most hospitals and community health centers in Indonesia still use conventional infusion devices to treat patients. When the intravenous fluids run out, they must be replaced immediately with new fluids or stopped according to doctor's instructions. However, due to the limited number of nurses and a large number of patients, nurses often forget to monitor and replace infused fluids [8]. If this happens and is not treated immediately, it will be dangerous for the patient, blood will flow into the Infusion hose and freeze in the Infusion hose so that it interferes with the smooth flow of intravenous fluids. Besides, if the pressure in the infusion is unstable, the blood that is frozen in the infusion hose can turn back into the blood vessels. The frozen blood can circulate throughout the body and can clog blood capillaries in the lungs, causing embolism in the lungs [9]. As such, regular management of monitoring and replacement of intravenous fluids play an important role in patient care.
Based on field conditions, it is necessary to update the infusion pump so that it does not need to be watched closely as is done now [10].

Several studies related to infusion device monitoring systems have been carried out by several health studies. Zhang et al. have made infusion monitoring devices using wireless devices plus RFID tags to identify patients [11]. This tool uses ATmega128, photodiode sensor, ultrasonic sensor, optocoupler sensor, with connections using ZigBee. A study conducted by Ruslan et al. has established an infusion fluid monitoring system based on indicators of condition and infusion fluid rate using Wi-Fi networks [6]. Similar research was also created by Yusro et al. by developing a smart device SICoMS (Smart Infusion Control and Monitoring System) that uses the web and can be run on android smartphones [12]. This study is to provide a tool for monitoring the condition of the infusion bag volume, control the dose of drip per minute, and be able to detect blood entering the infusion hose. The infusion bag volume is written in percent. The dose of drip per minute can be adjusted to upper and lower limits. The information is presented on the web. All work can be controlled remotely using internet technology.

2. Methods

This study uses research and development method through stages including study literature, identify problems, analyze system requirements, design, and test systems. Figure 1 shows the design of the system.

Figure 1 consists of the input, process, and output sections. The input system consists of a load cell sensor, a photodiode, and an optocoupler. A load cell sensor accepts pressure values, a photodiode sensor that detects drip drops, and an optocoupler sensor that detects blood entering the infusion hose. After data received by the sensor, it will be processed by the NodeMCU control system. The output system consists of a buzzer, a status LED, and a servo motor. Buzzer under normal circumstances will silence, then sound when the infusion device changes to standby or dangerous condition. The status LED will emit the color according to the condition of the infusion device, red if dangerous, yellow if standby, and green under normal conditions. The servo motor will clamp the infusion hose so that the number of drops detected is following the settings made through the website. All of the information will display on the website, nurses will more easily monitor the condition of the patient's infusion and adjust the number the dose of drip per minute that the patient needs.

3. Results and discussion

3.1. Load cell sensor test results

The sensor test aims to determine the suitability between the mass read on the sensor and the measured mass on the Fleco F-117 digital scale. The load cell sensor test results are shown in Table 1.
Table 1. Load cell sensor test with digital scales.

| Criteria | The measurement results of the scales (grams) | The results of reading the load cell sensor (grams) | Error (%) |
|----------|-----------------------------------------------|--------------------------------------------------|-----------|
| Compatibility of the measurement results of the scales and the load cell | 64 | 66 | 3.12 |
| | 114 | 117 | 2.63 |
| | 164 | 167 | 1.83 |
| | 214 | 218 | 1.87 |
| | 264 | 268 | 1.51 |
| | 314 | 318 | 1.27 |
| | 364 | 369 | 1.37 |
| | 414 | 418 | 0.96 |
| | 514 | 518 | 0.78 |
| | 614 | 614 | 0.00 |

3.2. Optocoupler sensor test results

Sensor testing aims to determine the suitability of the optocoupler reading related to the presence or absence of blood in the infusion hose. It is expected the optocoupler sensor can detect the difference between intravenous fluids and blood. The test results are shown in Table 2.

Table 2. Optocoupler sensor test

| Condition | Criteria | Voltage measurable $D_0$ (volt) | Read in NodeMCU (0/1) | Test result |
|-----------|----------|---------------------------------|-----------------------|-------------|
| No Blood  | 0V       | 0.101                           | 0                     | Good        |
| Blood     | 3.3V     | 3.241                           | 1                     | Good        |

3.3. Photodiode sensor test results

Sensor testing aims to compare of droplet calculations through photodiode and droplet calculations manually. Before that, the value is read through the Analog to Digital Converter (ADC) circuit to get the precision sensor reading capability. The results of the photodiode sensor test are shown in Table 3.

Table 3. Photodiode sensor test

| Criteria | Time (minutes) | Calculation of the manual droplet (tpm) | Results of the reading of the droplet (tpm) | Error (%) |
|----------|----------------|----------------------------------------|---------------------------------------------|-----------|
| Compliance of manual calculation and sensor reading | 1 | 16 | 16 | 0.00 |
| | 2 | 16 | 16 | 0.00 |
| | 3 | 16 | 16 | 0.00 |
| | 4 | 16 | 16 | 0.00 |
| | 5 | 16 | 16 | 0.00 |
| | 6 | 139 | 139 | 0.00 |
| | 7 | 139 | 137 | 1.44 |
| | 8 | 139 | 133 | 4.32 |
| | 9 | 139 | 132 | 5.03 |
| | 10 | 139 | 130 | 6.47 |
3.4. Servo motors test results
Testing on servo motors aims to determine the suitability between program commands/instructions and the direction of servo motor movement (in degrees). Before that, programming is done at each angle to be measured. The results of servo motor testing are shown in Table 4.

Table 4. Testing angles of servo motors.

| Criteria            | Command angle (degree) | Moving motor angle (degree) | Error (%) |
|---------------------|------------------------|-----------------------------|-----------|
| Servo motor moves according to program commands/instructions | 0                      | 0                           | 0.00      |
|                     | 5                      | 5                           | 0.00      |
|                     | 10                     | 10                          | 0.00      |
|                     | 20                     | 20                          | 0.00      |
|                     | 30                     | 30                          | 0.00      |
|                     | 40                     | 40                          | 0.00      |
|                     | 45                     | 45                          | 0.00      |
|                     | 90                     | 90                          | 0.00      |
|                     | 135                    | 135                         | 0.00      |
|                     | 180                    | 180                         | 0.00      |

3.5. Status LED test results
On the status LED test RGB (Red, Green, Blue) is performed to determine the color match between program commands/instructions and the color of the LED output. This is done by giving a program command on each pin. RGB LED testing results are shown in Table 5.

Table 5. Status LED test.

| Pin conditions | Criteria color | Results color | Testing results |
|----------------|----------------|---------------|-----------------|
| R  | G  | B  |                   |                |
| 1  | 0  | 0  | Red              | Red            | Good           |
| 0  | 1  | 0  | Green            | Green          | Good           |
| 0  | 0  | 1  | Blue             | Blue           | Good           |
| 1  | 1  | 0  | Yellow           | Yellow         | Good           |
| 0  | 1  | 1  | Aqua             | Aqua           | Good           |
| 1  | 0  | 1  | Purple           | Purple         | Good           |

3.6. Buzzer/sound test results
Testing is carried out to ensure the components work as reminders (sounds) on the system. Testing is done by giving logic 0 and 1 to the buzzer input pin. The test results are shown in Table 6.

Table 6. Buzzer test.

| Input to buzzer | Criteria      | Sound (Yes / No) | Test results | Remarks (volt) |
|-----------------|---------------|------------------|--------------|----------------|
| 0               | No sound      | No               | Good         | 0.101          |
| 1               | sound         | Yes              | Good         | 3.241          |

3.7. Overall system test results
System testing aims to ensure that all devices work properly according to the commands that have been given. Testing is done by accessing the web interface and seeing compatibility with the device that has been paired on the infusion device. The test is carried out in 3 circumstances, namely normal or safe, alert, and hazardous. Normal conditions are when all system components work properly. The standby condition is when the remaining intravenous fluid is between 1-10% and the alarm is on. Dangerous
conditions are when the intravenous fluid runs out, blood is detected in the tube, and when the intravenous fluid does not drip. The test results are shown in Table 7.

Table 7. Overall system testing.

| Liquid balance (%) | Number of drops (tspm) | Drops limits (tspm) | RGB LED color | Buzzer | Hose condition | Web notification | Test results | Status |
|--------------------|------------------------|--------------------|---------------|--------|----------------|------------------|-------------|--------|
| 27                 | 93                     | 95-105             | Green         | Off    | No folded, no blood | Remaining liquid 1%, standby alarm sounds | Good        | Normal conditions |
| 1                  | 45                     | 45-55              | Yellow        | On, slow pause | No folded, no blood | Blood detected, danger alarm sounds | Good        | Standby condition |
| 25                 | 92                     | 95-105             | Red           | Live, fast pause | Not folded, no blood | No dripping liquid, danger alarm sounds | Good        | Danger conditions |
| 25                 | 0                      | 95-105             | Red           | Life, fast pause | Folded, no blood | The liquid does not drip, the intravenous fluid runs out, the danger alarm sounds | Good        | Danger conditions |
| 0                  | 0                      | 95-105             | Red           | Live, fast pause | Not folded, no blood | The liquid does not drip, the intravenous fluid runs out, the danger alarm sounds | Good        | Danger condition |

Table 7 obtained information that the system can activate the alarm at the time of standby i.e. the remaining 1% - 10% infusion fluid. The alarm is also active at the moment of danger when the liquid does not drip, run out, or blood is detected in the hose. In addition to the alarm that sounds, notifications on the web are also following system conditions and data can be continuously updated on the website (Figure 2).

Figure 2. Display of infusion monitoring system website (http://www.apki.kpmunj.org).

4. Conclusions

Based on testing and analysis of measurements made as a whole from the monitoring and control of infusion, the following conclusions can be obtained 1) the device can read the weight of the infusion bag, detect drops and detect blood in the infusion hose; 2) the tool has a reminder (alarm) in sound and color light found on the tool and the web display, where the alarm will sound on and the status LED
change color light when the system is on standby and danger; 3) mass reading has an error value of 3.12%, droplet reading has an error value of 6.47%, and blood detector has an error value of 0%; 4) this tool can remotely manage the dose of drip per minute via the web, and 5) a system built using a website display can provide important information to nurses/doctors about the patient's infusion condition.

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