Design and development of a monitoring and controlling system for multi-intravenous infusion

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Abstract. Recently, many of conventional infusion control tools which have functions to control the drops of infusion fluid and to monitor the volume of infusion fluid. Because it work manually, it has low level of accuracy and low efficiency. So that, in this research has designed a device that could monitor and control the drops of infusion fluid for multipoint (multi intravenous) through online application. On hardware part, photodiode and LED was used to detect the drops of infusion fluid, a sliding potentiometer and simple modified spring was used to detect the volume of infusion fluid. In this research was also implemented a mechanical which use motor servo to set the speed of drops of infusion fluid. WEMOS and MCU node has been designed as main control to controlling the whole of system. The device was equipped with ESP8266 as interface to internet network. An administrator can monitoring and controlling the system through offline or real time through a website application that has been built. Based on the testing result, as functionality the system was working well. The device could detect the drops of infusion fluid with 100% of accuracy and could control the volume of infusion fluid with 99% of accuracy. Total of maximum drops per minute that could detected by system was 135 DPMs with average of transferring delay was 1.95 second.

1. Introduction
Infusion is an activity to inject fluid into patient intravenous to supply the body's needs and an action of treatment and give a nutrition as supplement. Usually, the patients that being treated in the hospital always given intravenous infusion both of critical or recovering patients [1]. Monitoring of Infusion condition should be done in one to two per hour to make sure the infusion are stable according to patient needs. An important thing that should be noticed are: total drops per minute is 15-20 drops for adult and 45-60 drops per minute for child [2]. Monitoring of volume of infusion fluid also important because if the infusion fluid runs out or empty it will cause the air enter into blood vessel. In current condition, there are many medical personnel which controlling the infusion fluid conventionally. They count drops per minute manually using timer, it is sure chance of having an error. That condition can be worst if the infusion installed quite a lot.

This system through wireless communication make the activity of monitoring and controlling of the infusion fluid easier, faster, more flexible, and also can apply into multi device. Some of research have been successful to develop a system to monitoring and controlling the infusion fluid. Research by Umchid, et.al [1], had designed a controlling system of infusion fluid volume through mobile phone using Bluetooth. That system was limit by one device and that access limited by distance of Bluetooth coverage. Another research by Ajibola, et.al [2], had implemented a load cell to measure the infusion fluid volume and monitor it online. In this research, a device has been built that could detect the drops of infusion fluid with 100% of accuracy and could control the volume of infusion fluid with 99% of accuracy. Total of maximum drops per minute that could detected by system was 135 DPMs with average of transferring delay was 1.95 second.
volume but the result only could be seen on fix display. The developing of infusion monitoring system through wireless network had demonstrated in studies [3-9] and multi node system was applied in study [5] but it could only local access. Another study, had implemented infusion monitoring system through internet network so it could be accessed with no limit of coverage area [10-12]. However, the previous proposed research does not yet support a system that is capable of remote monitoring and controlling over internet networks in multinode applications. Therefore, in this paper was implemented the system of controlling and monitoring infusion droplets through internet network that applied for multi node.

The system that was developed, consists of hardware for data acquisition and website application for display. A photodiode circuit and LED was used to detect infusion droplets. Potentiometer circuit which combine with modified spring was used to measure the infusion volume. A motor servo was implemented to control the speed of infusion drops. WEMOS and MCU node as main control of system and responsible in transferring the data into internet network. The data from the node sensor was transmitting to a database in real time called firebase. Authorized person or nurse that have an access and have a concern can be monitoring and controlling infusion fluid of the patients through web application.

2. Method

2.1. System Design

Figure 1 shows the system that proposed in this research. This system was designed to monitoring the function of volume, total of drops and control the speed of infusion droplets and could shows them through online using website application. The system that have been designing was supported to multi end users (devices) where in this study had been simulating for two end devices. The end device can be added according the needs of patient treatment which is controlling by hardware and it has registered on application. Detail of system design (both of hardware and software) shown in Fig.2.

![Figure 1. Design of infusion monitoring system](image-url)
The device consists of LED circuit and photodiode to detect infusion droplets, circuit of voltage divider was use potentiometer to estimating the infusion volume and circuits of motor servo as mechanic actuator to control the speed of infusion droplets. WeMOS as main control make a computation and transferring the data through internet network. This data then sent to the firebase to be saved and will be forwarding to the users whom have an interest. An important information such as type of infusion fluid, volume of infusion fluid, and speed of infusion droplets will be showed on website page. This system also equipped with feature to control the speed of infusion droplets. The flow of work this proposed system showing in Fig.3

First step was initialization to activating all of variables on WeMOS. Then WeMOS would control the connectivity of Wi-Fi network through ESP system to be processed on control mode. The control
mode was consist of two functions, they are to control the infusion droplets and sensor reader. Main control unit was counting the total of infusion droplets, infusion volume and controlling infusion speed.

2.2. Hardware Design
The infusion volume detector’s circuit was designed using sliding potentiometer that modified by a spring. The function of this circuit was as a voltage divider actually which has a variance value according to the potentiometer resistance resulting from the changes of infusion bottle weight. The decimal value which produced from analog to digital conversion was representing the infusion volume. The schematic circuit of system is showing in Figure 4.

Infusion droplets detector was designed using LED and photodiode. The main controller would calculate the number of infusion droplets per minute by counting the delay between first drop and second drop. DPM (Drop per Minute) value was obtained from equation 60/delay in second. Figure 5 showing infusion drop detector’s circuit.

![Figure 5.](image)

**Figure 5.** (a) Detector circuit (b) Implementation of detector.

Motor servo was the main component of infusion speed regulator mechanical circuit. The modified motor servo was able to press the infusion hose so that the infusion droplets speed could be adjusted. The instruction can be transmitted through the application in the form of angle rotation value of motor servo. The smaller angle value of movement of motor servo, it would reduce the speed of infusion droplets, conversely the larger angle value of movement of motor servo it would accelerate the speed of
infusion droplets. Table 1 shows the command and the rotation of motor servo. The implementation of system is shown in Figure 6.

### Figure 6. Implementation of infusion droplets speed regulator

#### Table 1. Command to servo motor

| Command | Rotation |
|---------|----------|
| 0       | 8°       |
| 1       | 7°       |
| 2       | 6°       |
| 3       | 5°       |
| 4       | 4°       |
| 5       | 3°       |

2.3. Application Design

Application software was designed to communicate with another device through TCP/IP. This application was a webpage which could showing figures and text. The main information that can be shown are the data of patients, room numbers, volume, type of infusion fluid, and speed of infusion droplets as shown in Figure 7.

#### Figure 7. Application’s display of information system

The application requested the data to firebase to send the information. This process was real time so that every changes to the device could be seen in application in a short time. There are two types of access in this application, they are as administrator and medical staff. Both of them have the same authentication, it was for infusion monitoring, to edit the patients data and registering the new patients. But who have an authority to create or registering of medical staff account could be done by administrator.
3. Result and Discussion

3.1. Infusion Volume Module

The testing of this module was aimed to determine the accuracy of the device in estimating infusion volume. The testing was done by comparing the actual volume in the infusion bottle to the calculation results by microcontroller. The testing for each node is shown in Table 2.

| Volume (ml) | First Device | Second Device | % Error |
|-------------|--------------|---------------|---------|
| 500         | 502          | 502           | 0.4     |
| 450         | 454          | 454           | 0.88    |
| 400         | 407          | 400           | 1.75    |
| 350         | 354          | 350           | 1.14    |
| 300         | 319          | 300           | 6.33    |
| 250         | 252          | 252           | 0.8     |
| 200         | 201          | 201           | 0.5     |
| 150         | 150          | 150           | 0       |
| 100         | 101          | 108           | 1       |
| 50          | 50           | 49            | 2       |
| 0           | 0            | 0             | 0       |
| Mean        |              |               | 1.16    |
|             | First Device | Second Device |         |

From the test result shown in Table 2, each device provides 99% accuracy at 50 ml intervals. Errors could be caused by the position of the spring and the potentiometer when it had been stretching was not linear, because of this error value relatively small so it does not have any negative effect to the patients. This system also designed to be able to give an alarm when the infusion volume approach ≤ 51 ml. In this condition, the LED indicator on the device will be active and send the status “empty infusion” to the database. Table 3 was the result of alarm system testing that had been done.

| Volume | Expected output | Output system |
|--------|-----------------|---------------|
| ≤ 50ml | LED “ON”        | LED “ON”      |
| 100ml  | LED “OFF”       | LED “OFF”     |
| 200ml  | LED “OFF”       | LED “OFF”     |
| 300ml  | LED “OFF”       | LED “OFF”     |
| 400ml  | LED “OFF”       | LED “OFF”     |
| 500ml  | LED “OFF”       | LED “OFF”     |

3.2. Infusion Droplets Detector Module

Droplets Detector Module Testing was aimed to measure the accuracy of the device in detecting infusion droplets. In the first scenario, the speed of infusion droplets had set constant but calculation of the number of infusion droplets was testing in different time. The result of this test scenario shown in Table 4.

Table 4. Infusion droplets detection
| Experiment | Number of droplets |
|------------|--------------------|
|            | Actual  | Proposed device |
| 1          | 16      | 16               |
| 2          | 22      | 22               |
| 3          | 21      | 21               |
| 4          | 20      | 20               |
| 5          | 18      | 18               |
| 6          | 23      | 23               |
| 7          | 22      | 22               |
| 8          | 19      | 19               |
| 9          | 26      | 26               |
| 10         | 18      | 18               |

In the second scenario, the speed of infusion droplets per minute was varies in 10-140 DPM. The purpose of this testing was to determine the maximum speed that could be detected by the device. From the testing, the device could detecting infusion droplets up to 135 DPM. A larger number of DPM could be cause reading errors, because the gap between droplets became increasingly invisible.

3.3. The Speed Controller Module of Infusion Droplets
The testing on droplets speed controller module was carried out to determine the speed of the infusion droplets if get any command from the application. The result can be seen in Table 5. Every command that given through the application will be executed by main controller to drive the motor servo which its speed increasing linearly. The number of DPM can be adjust by calibrating to the angle rotation of the motor servo.

| Command | Rotation | DPM |
|---------|----------|-----|
| 0       | 8°       | 27  |
| 1       | 7°       | 45  |
| 2       | 6°       | 51  |
| 3       | 5°       | 65  |
| 4       | 4°       | 78  |
| 5       | 3°       | 85  |

3.4. Testing of Application Page
The application page contains of all information that related to infusion conditions. The application also displays the patient’s identity and the number of patient’s room. Figure 8 depicted an example of webpage display when the system was running. If there were an additional patients, the administrator would registering and activating the device until the synchronization process succeeded then the information would be displayed on the application.
Figure 8. (a) The status of infusion patients (b) List of active patients

### 3.5. Delay

Delay testing had done by calculating the time interval of sending data (in second) from the device until it displayed on the application. The testing was trial in 5 times and the result as can be seen in Table 6.

| Experiment | Delay (s) |
|------------|-----------|
| 1          | 1.24      |
| 2          | 2.12      |
| 3          | 2.54      |
| 4          | 2.19      |
| 5          | 1.66      |
| **Mean**   | **1.95**  |

### 4. Conclusion

This paper had proposed a design and implementation of an intravenous monitoring and controlling system through the internet network. This system supports multi device applications and transferring the information in real time. The system that has implemented consist of hardware device and software application. The hardware part has function to detect the droplets, to measure the volume and to control the speed of infusion droplets. The software was an application that has function to display the patient’s information which related to the infusion conditions. This application is web based as an interface for user that have authentication to access the system. The device could be easily installed on the existing infusion bottle. From the testing, the device was able to measure the infusion volume and to detect the
infusion droplets with each 99% and 100% of accuracy. The maximum DPM that could be detected by the device was 135 DPM. The application software was equipped with an infusion bottle animation that representing infusion volume so that it can make easier medical staff in monitoring the patients. This system was needs average time process of 1.95 second to transmit the data from device to application.

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