Development of Smart Infusion Control and Monitoring System (SICoMS) Based Web and Android Application

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Abstract. This study aims to develop an automatic system of tools infusion that can monitor the condition of the infusion volume and monitor the condition of droplets performed remotely using web technology and Android applications. The test activities of SICoMS is testing heavy on the loadcell sensor, HX711 module testing, testing of droplets on the photodiode sensor, data communications testing, web, and Android testing. SICoMS design has been made simple with two main functions are remote monitoring for the condition of the contents/detection volume of infusion fluids and drips or absence of intravenous fluids. The status intravenous fluid volume used by patients divided into three categories namely: Safe: intravenous fluid condition > 10%; Standby: the condition of the infusion liquid 5%-10% and Empty: 0% condition intravenous fluids. Heavy testing the infusion bag with three different volume of 500 mL, 100 mL and 25 mL generate accurate results that are displayed on SICoMS application. At the time of infusion fluid is completely discharged, the red indicator on the display flashes SICoMS application and buzzer at the infusion apparatus will beep to inform the patient's family/patient.

1. Introduction

Generally, intravenous fluid therapy is the most commonly prescribed inpatient medication in hospitals around the world [1, 2]. Intravenous infusion pump systems are among the most frequently used technologies in health care. An estimated 90% of hospital patients receive intravenous medications via infusion pumps [3].

Smart Infusion Control and Monitoring System (SICoMS) is an innovation in the field of health which aims to help nurse doctors and patient families to monitor the patient's infusion bag volume easily from a distance with the help of Internet of Things (IoT) technology.

Using a heavy sensor used as a volume sensor of the infusion bag and an infrared sensor used to detect the presence or absence of infusion droplets which then the data will be sent to the cloud server with Arduino and GPRS modules. Data can be accessed via web browser or Android App.

Why is this monitoring and control infusion important? In the hospital, for inpatient patients, this infusion is necessary because the average patient lacks fluids [4]. It is important to prescribe intravenous fluid for patients according to their individual condition/status [5]. Intravenous fluids are drugs and have an indication, a dose, and expected and unintended effects. The type and amount of fluid given to patients are both important and can either hasten or slow recovery depending on how they are got it [1].
Fluid administration is frequently used in hospitalized patients. The most common reasons for fluid administration include hypotension, shock, sepsis, hypovolemia, replacement of fluid losses, and oliguria [6]. Drips and the rate of drips should be taken into account at the appropriate level. Therefore, in hospital, intravenous fluid management plays an important role in patient’s care [7, 8].

To improve the effectiveness of the nurse’s performance in managing the infusion fluid need to avoid monitoring manually but have applied the technology. Smart pumps allowing automated relays of vasoactive drug infusion pumps reduce the rate of hemodynamic incidents by half and also improve the quality and the organization of care in the ICU by decreasing the number of nursing and medical tasks interrupted and reducing the time dedicated to this current high-risk procedure [9, 10].

The purpose of this research is to make monitoring and control system of infusion fluid which can be accessed through the internet with the web browser and Android Application. The monitoring data is the volume of the infusion bag and the infusion flow status. The infusion bag volume consisted of 3 categories: the safe status where the infusion volume was greater than 10%, then the standby condition where the infusion volume was between 5% - 10% and the condition was depleted, i.e. the infusion volume reached 0%. If the infusion volume reaches 0% then the buzzer will sound and the led will blink.

2. Method
The research method used is research and development (R & D) method using ADDIE (Analyze, Design, Develop, Implement, Evaluate). Research data in the form of quantitative data and qualitative data. Quantitative data is measurement data using electronic measuring instrument. Qualitative data were obtained in the form of assessment, suggestion, and comment from the technical expert and health expert on SICoMS performance. Development of SICoMS using an Android and Arduino platform. Arduino is an open-source project that started in 2005 in interaction design institute as a low-cost development kit for applications with microcontrollers by Atmel [11-13]

In Figure 1 described loadcell is used as a weight sensor which aims to measure the volume of the infusion bag. The volume of the infusion bag is obtained by using the physical formula i.e. rho = mass/volume, where rho is the density of water 1 gram / mL. Infrared sensors are used as infusion flow detection which the way it works is infrared led will emit infrared rays and when there is a hitch then the infrared will be reflected back which will concern the red photodiode and when there is no obstacle infrared is not hit photodiode drip flow of the infusion will make the infrared sensor output will form the pulse. If there is no droplet then there is no pulse to detect the presence or absence of droplets by detecting a pulse or not at the infrared sensor output.

The mass of the infusion bag and the infrared sensor output signal data will be sent by the embedded system to the cloud server by accessing the data server addressed with the GET parameter at the end of the server address. The server mass data will be converted to volume and the infrared sensor output signal will be converted into the presence or absence of drip on the infusion.

To make sure this algorithm works we do a measurement. The measurement data will be analyzed by comparing the measuring result on the SICoMS system equipment with the calculation result. Some of the testing activities that are for SICoMS are as follows:

- Weight Testing on Loadcell Sensors
- HX711 Module Dual-Channel 24 bits ADC Loadcell Module Test
- Drop Test on Photodiode Sensors
- SICoMS Data Communication Test
- SICoMS Web Display Testing
- SICoMS Testing using Android
3. Results and discussion

3.1. Weight testing on loadcell sensors
The loadcell sensor is tested by calibrating some objects that have been written heavily on the wrapper [14]. The result of weight testing on the loadcell sensor is shown in Table 1.

| Type of Measure (Nett) | Net Weight Object Score | Value Loadcell |
|------------------------|-------------------------|----------------|
| 1kg                    | 1000 gr                 | 999 gr         |
| 85 gr                  | 85 gr                   | 85 gr          |
| 40 gr                  | 40 gr                   | 40 gr          |

The weight test result of the loadcell sensor reads is equal to the net weight of the specimen. Technical testing is done by running a loadcell program that is displayed using the Arduino serial ID monitor facility 1.8.5 with COM24 port. After ensuring that testing of objects with three different weights yielded correct readings, the test was continued by testing three different intravenous drip bags. The results of the infusion bag weighing test are shown in Table 2.

| Infusion bag (Nett) | Value Loadcell | Infusion Volume (mL) |
|---------------------|----------------|---------------------|
| 500 mL              | 558 gr         | 500 mL              |
| 100 mL              | 124 gr         | 100 mL              |
| 25 mL               | 29 gr          | 25 mL               |

In Table 2, it is seen that the results of the infusion volume test that reads the loadcell sensor are the same as the contents of the infusion bag/bottle. In 500mL infusion bag there is 500mL water- injection and NaCl 4.5 gram, this means the net mass of infusion bag is 500mL water mass added Total Mass of NaCl 4.5gram to 504.5 grams. The mass of infusion bag in the empty state that is 20 grams. This means a gross mass of 524.5 grams.
Load cell measure infusion bag with total mass 558 gram there is difference 23.5 gram so an error at loadcell that is 23.5 / 524.5 * 100% = 4.48%.

3.2. HX711 module dual-channel 24 bit ADC loadcell module test
Testing on the HX711 module is intended to determine the amount of voltage generated by the HX711 module while ensuring that the amplifier module, as well as the ADC, is working properly. The test technique is by installing three infusion pockets which have the different volume of contents, then perform measurements using Voltmeter on A+ and A- feet, the measured results are shown in Table 3.

| Infusion bag (Nett) | The voltage difference between A+ and A- |
|---------------------|-----------------------------------------|
| 0 mL                | -0.2 mV                                 |
| 500 mL              | 0.1 mV                                  |
| 100 mL              | -0.1 mV                                 |

3.3. Photodiode sensor testing
Photodiode sensor testing aims to determine whether the infusion fluid drips or does not drip [15]. This is especially important when SICoMS is used to inform the physician/nurse to monitor the intravenous fluids administered to the patient. The results of photodiode sensor testing are shown in Table 4. below.

| Infusion fluid condition | Value at Photodiode Output |
|--------------------------|----------------------------|
| Drips                    | 4.9 V                      |
| Not drips                | 0 V                        |

3.4. SICoMS data communication test
The data communication test between GSM / GPRS shield and Arduino Uno is performed to see the response of GSM/GPRS shield to the information provided by Arduino [16]. Tables 5a and 5b show the results of the SICoMS data communication test.

| AT Command | Response from GSM/GPRS Shield |
|------------|-------------------------------|
| +CREG: 1,1  | OK                            |
| AT&F0       | OK                            |
| ATE0        | OK                            |
| AT+CME=2    | OK                            |

| AT Command | Response |
|------------|----------|
| AT+CGATT?  | +CGATT:1 OK |
| AT+CGATT=1 | OK       |
| AT+CGDCONT=1,“IP”,”internet” | OK |
| AT+CGACT=1,1 | OK     |
| AT+CIPSTART=”TCP”,”139.59.249.82”,80 | CONNECT OK |
### Table 5b. Cont.

| AT Command      | Response                                      |
|-----------------|-----------------------------------------------|
| AT+CIPSTATUS    | +CIPSTATUS:0,CONNE                            |
|                 | CT OK                                          |
|                 | 1,IP INITIAL                                  |
|                 | 2,IP INITIAL                                  |
|                 | 3,IP INITIAL                                  |
|                 | 4,IP INITIAL                                  |
|                 | 5,IP INITIAL                                  |
|                 | 6,IP INITIAL                                  |
|                 | 7,IP INITIAL                                  |
|                 | OK                                            |
| AT+CIPSEND      | +CIPRCV:161,HTTP/1.1                          |
|                 | 200 OK                                         |
|                 | Date: Sun, 19 Nov 2017                        |
|                 | 03:31:50 GMT                                  |
|                 | Server: Apache/2.4.18                         |
|                 | (Ubuntu)                                      |
|                 | Content-Length: 13                            |
|                 | Content-Type: text/html; charset=UTF-8        |
|                 | suksessimpan                                  |

3.5. **SICoMS application preliminary testing**  
Testing of SICoMS website display is done through URL address: http://sicoms.myusro.id/ which is designed to monitor infusion. Figure 2 shows the display form of SICoMS. Display has 2 main menu, namely: Patient Data and Monitoring. The Monitoring menu has the features: 1) Status Description (Safe: infusion fluid condition> 10%; Standby: infusion fluid condition 5% -10% and Out: 0% infusion fluid condition); 2) Infusion Status Table (Status ID; Name of Patient: Infusion Type (500 mL, 100 mL and 25 mL), Volume (progress volume of infusion) Indicator (red, yellow, green) and Drop Status (hatch or no drip).

![SICoMS monitoring menu view](image_url)

**Figure 2.** SICoMS monitoring menu view.

The second menu contained in the SICoMS application is Patient Data (Figure 3) which features:
3.6. SICoMS testing using android

Unlike smart infusion pumps, data can only be viewed locally or offline, nurses or doctors should go to the infusion to see the patient's infusion. SICoMS technology allows infusion fluid volume data and infusion droplet status to be seen anywhere via the internet.

Testing conditions of the content/volume of intravenous fluid that has been used by the patient and the condition of dripping or dribbling of intravenous fluids may be monitored using SICoMS application either through the website or Android app. At the time of infusion fluid is completely discharged, the red indicator on the display flashes SICoMS application and buzzer at the infusion apparatus will beep to inform the patient's family/patient.

4. Conclusions

Based on the research that has been done, it can be taken some conclusions, as follows:

- SICoMS have to be designed with two main functions: remote monitoring for infusion fluid volume and detection of infusion fluid.
- The loadcell sensor can be used as the volume sensor of the infusion by converting the liquid mass to the infusion volume and loadcell mass measurement error of 4.48%.
- Infrared sensors can be used as sensors to detect the presence or absence of drip drops.
- Arduino and GPRS A6 Thinker modules can be used as embedded systems that access cloud servers to send data mass of bag infusion and data signal output sensor infrared to the database server.

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