Design and Development of a Monitoring System for Saline Administration

Sumet Umchid, Pakkawat Kongsomboom, and Matuve Buttongdee

Abstract— **The objective of this work is to design, develop and construct a saline monitoring system to facilitate medical staffs in order to notify them when the saline level is almost empty or below the setting value. After installing the saline bottle to a load cell module, the load cell will be used to measure the weight of the saline. The signals from the load cell will be transferred to a microcontroller to convert saline weight to saline volume. The volume of the saline is then displayed on the LCD screen of the developed system and on the mobile phone screen of the medical staff via the application on the mobile phone. If the saline volume is less than or equal to the setting volume, the alarm will be activated by turning on the speaker and the alert message will also be sent to the medical staffs via the application on the mobile phone using Bluetooth technology. There are 4 tests to validate the performance of the developed system. The first test is performed by comparing between the weight measured with the developed system and the weight of the standard weight. The results show that the percentage errors between them are within 0.43%. The second test is to examine the relationship between the weight measured by the load cell and the saline volume dispensed from the infusion pump machine. The relationship between the average weights and the volumes is found to be approximately 1 g per 1 ml. The third test is carried out by comparing between the volume measured with the developed system and the volume measured with the infusion pump system. The results indicate that the percentage errors are within 2.13%. Finally, the minimum volume detected by the developed system is found to be 4 ml. The results indicate that the developed system is able to help in monitoring the saline volume in the bottle from a distance and give the notification when the saline level reaches the pre-defined critical volume.**

Index Terms— **saline monitoring system, load cell, Arduino microcontroller**

I. INTRODUCTION

As the world population increases, the need for health care services also enhances. However, the care people with adequate skill in the hospital are not sufficient. Since medical technology has been improved significantly during the past few decades, a number of health monitoring systems have been developed [1-6].

Intravenous infusion is one of the most important clinical treatments. The progress and flow rate of intravenous infusion must be strictly controlled to avoid serious medical accidents [7]. Therefore, when normal saline is placed intravenously into any patient, the saline level musts be constantly monitored by nurses or patient's relatives. If there is no change of a new saline bottle as soon as it is totally consumed, the blood from vein will move back into the saline bottle due to the difference between the pressure inside the empty saline bottle and the blood pressure. This may cause tiredness from lack of red blood cells (RBCs) in the patient's blood [8]. Fortunately, some specialized medical devices such as infusion pump can solve these problems [9-10]. The infusion pump is capable of controlling the flow rate of the infusion fluid, and cutting down infusion tube in case of reflux. However, the infusion pump is quite expensive so the large scale applications are limited. Also, it is not able to display the current saline volume on the screen and it cannot send the notification to the medical staffs personally.

Consequently, this paper describes the design and development of a reliable, cost effective and automatic saline level monitoring system, which could be easily constructed in any hospitals to prevent the patient from getting harmed and protect their lives during saline feeding period. The developed system is able to indicate the current saline volume in the bottle. In addition, when the saline volume is below the setting volume, the alarm will be activated and the notification message will also be sent to the medical staffs via the application on the mobile phone using Bluetooth technology. This would accommodate medical staffs for observing the saline level from a distance and reduce the continuous on-site monitoring by the doctors and nurses.

II. METHODS

A schematic diagram of the developed saline monitoring system is presented in Figure 1.

The developed saline monitoring system is composed of the following parts:

(1) Load cell (model YZC-133) is used in this work as a weight sensor. The rated load of this load cell is 5 kg with maximum working voltage 15 V DC. It is placed on the medical Intravenous (IV) pole. The saline bottle is suspended on the load cell. This strain-gauge load cell converts the saline weight into electrical signals

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Manuscript received March 12, 2018; revised April x, 2018. This work was supported in part by the Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (Grant# 6143106).

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and then sends to the weight sensor amplifier module (HX711) before going to the microcontroller.

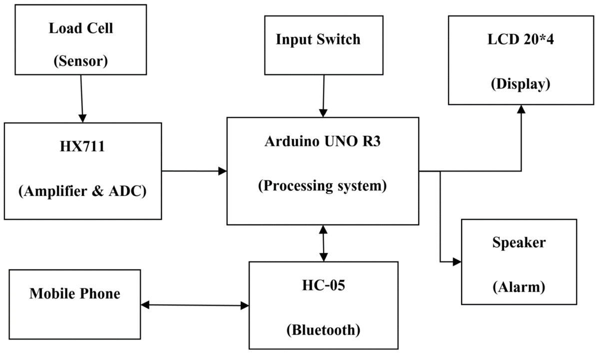

Fig. 1. Schematic diagram of the developed saline monitoring system

(2) Weight sensor amplifier module (model HX711) is an Integrated Circuit (IC), which consists of an amplifier and a precision 24-bit analog-to-digital convertor designed for weight scale to interface directly with a bridge sensor. This weight sensor amplifier module is placed between the load cell and the Arduino to amplify the signals from load cell and then convert them from analog signals to digital signals for the microcontroller (Arduino). The input interface of this weight sensor module adopts compact terminal that makes this module easier to connect the load cell. The output port uses sensor interface, which is compatible with Arduino I/O ports.

(3) Input switches are used to give input commands to the developed system. There are 4 micro-switches installed in the system. The first micro-switch is a tare weight switch used to reset the volume to zero ml before suspending the saline bottle. The second input switch is a silent switch used to turn off the alarm when the current saline volume is below the setting volume. The third micro-switch is a set alarm switch used to set the amount of saline volume that the system will give a notification. The last switch is a reset switch used to reset the program of the system to the initial values. The signals from these input switches will be transferred to the microcontroller unit.

(4) Arduino UNO R3 is an open source microcontroller used as a main processing and programming unit for receiving input information from the input switches and load cell, and then sending instruction to the Bluetooth module, speaker and LCD display. This microcontroller will convert saline weight to saline volume and then compare the current saline volume to the setting saline volume in order to give notification if the current saline volume is lower than the setting volume.

(5) Bluetooth module (model HC-05) acts as a transreceiver. This module becomes a transmitter when it transfers data from the microcontroller to the mobile phone. However, it will convert to a receiver when the input data are sent from the mobile phone back to the microcontroller.

(6) Mobile phone used in this work needs to be installed the mobile applications such as Bluetooth terminal or Arduino Bluetooth in order to communicate between the Bluetooth module and the mobile phone.

(7) Liquid crystal display (LCD) is utilized in the developed system to display the value of the current volume, instruction messages, input setting volume and alert messages.

(8) Speaker (model Future Kit FK240) is an audio signaling device used to give an alarm to the medical staffs and caretakers when the saline volume reaches the pre-defined critical value.

III. RESULTS

A photograph of the developed saline monitoring system is presented in Figure 2. The developed system is composed of 3 parts. (1) is the load cell module used to measure the weight of the saline. (2) is the signal cable connecting between the load cell module and the processing and displaying module. (3) is the processing and displaying module used to input, process and display data.

Fig. 2. A photograph of the developed saline monitoring system: (1) load cell module (2) signal cable and (3) processing and displaying module

Figure 3 represents the closer look photograph of the processing and displaying module. This module comprises of the following components:

(1) LED display is used to indicate the notification together with the alarm on the speaker and alert messages on the LCD display when the saline volume reaches the pre-defined critical value.

(2) Tare weight switch is used to reset the volume to 0 ml before suspending the saline bottle.

(3) Silent switch is used to deactivate the alarm when the current saline volume reach the pre-defined critical value.

(4) Set alarm switch is used to set the amount of saline volume that the system will give a notification.

(5) Reset switch is used to reset the program of the system to the initial values.

(6) USB port is used to connect data cable between the microcontroller of this module to the computer.

(7) Power supply port is used to supply 9 V DC to the module.

(8) Communication port is used to connect data cable between this module and load cell module.

(9) LCD display is used to display the value of the current volume, instruction messages, input setting volume and alert messages.

Fig. 3. A photograph of the processing and displaying module

To verify the performance of our developed saline monitoring system, the system was tested with 4 method.

The first test was performed by comparing between the weight measured with the developed system using load cell and the weight of the standard weight. The test was carried out by hanging the standard weights at the weights of 10, 20, 40, 60 80, 100, 150, 200, 250, 300, 350, 400, 450 and 500 g on the load cell module. The weight of those standard weights was measured 3 times each by the developed system. The graph between the average weight measured by the developed system in comparison with the weight of the standard weight is presented in Fig. 4.

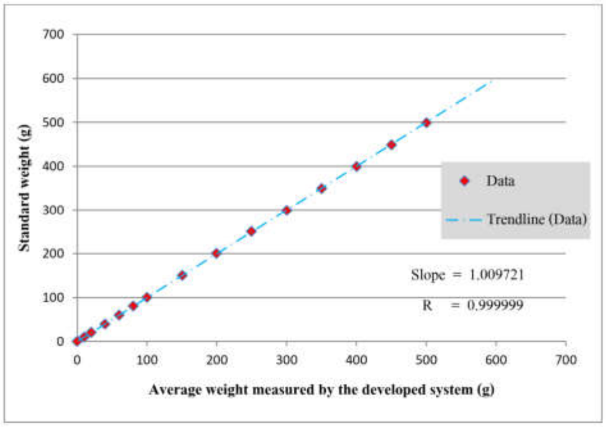

Fig. 4. The graph of the relationship between the weight of the standard weight and the weight measured by the developed saline monitoring system

The second test was to examine the relationship between the weight measured by the developed system using load cell and the saline volume dispensed from the infusion pump machine. The experiment was done by using infusion pump machine to control volume and flow rate of the saline that gave to a beaker suspending to the load cell module. This experiment was performed 3 times to obtain the relationship between the average weight measured by the developed system and the volume of the saline given from the infusion pump machine as shown in Fig. 5.

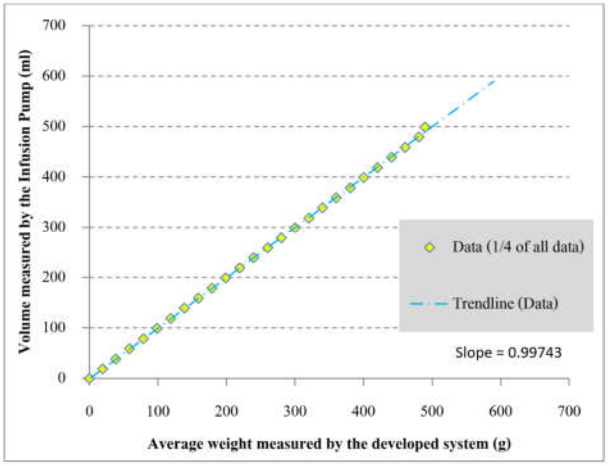

Fig. 5. The graph of the relationship between the weight measured by the developed saline monitoring system and the volume dispensed from the infusion pump machine

The third test is carried out by comparing the volume measured with the developed system to the volume measured with the infusion pump machine. The experiment was carried out using the same procedure as the experiment performed in the second test but the measurements from our developed system were in the unit of ml. The relationship between the volume measured with the developed system and the volume measured with the infusion pump machine is shown in Fig. 6.

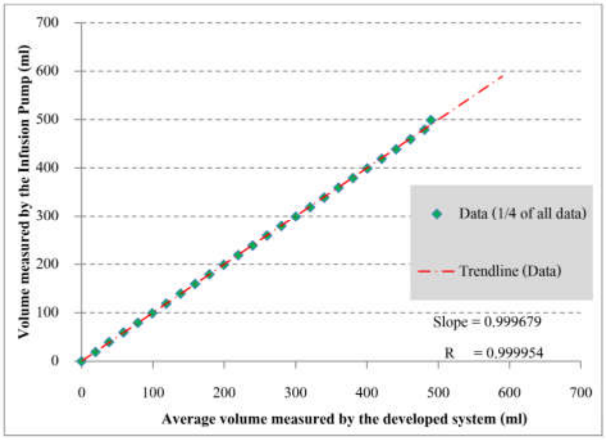

Fig. 6. The graph of the relationship between the volume measured with the developed system and the volume measured with the infusion pump machine

The 4th test was to perform the experiment in order to find the minimum volume detected by the developed system. This test was done by varying the alarm setting volume on the developed saline monitoring system from 50 ml to 0 ml as shown on Table 1 and then used the infusion pump machine to provide the desired saline volume to the developed system in order to indicate the minimum volume that can be detected by the developed system.

TABLE I
EXPERIMENT TO FIND THE MINIMUM VOLUME DETECTED BY THE DEVELOPED SALINE MONITORING SYSTEM

Alarm Setting Volume (ml)	Detection
50	√
40	√
30	√
20	√
10	√
5	√
4	√
3	x
2	x
1	x
0	√

IV. DISCUSSIONS

From the results, four tests were performed to validate the performance of the developed system. The first test was done by comparing between the weight measured with the developed system using load cell and the weight of the standard weight. The correlation coefficient of weight measured with the developed system and the weight of the standard weight was found to be 0.9999. These results indicate that the weights measured with the developed system are in an excellent agreement with the weights of the standard weight. In addition, the percentage errors were determined to be within 0.43%. The second test was implemented to examine the relationship between the weight measured by the developed system and the saline volume distributed from the infusion pump machine. The correlation coefficient of weight measured with the developed system and the saline volume dispensed from the infusion pump machine was found to be 0.9974. Therefore, these results show that the relationship between the average weights and the volumes is approximately 1 g per 1 ml. The third test was carried out by comparing between the volume measured with the developed system and the volume given from the infusion pump machine. The correlation coefficient of volume measured with the developed system and the volume measured from the infusion pump machine was found to be 0.9999 and the percentage errors were found to be within 2.13%. These results could confirm that the developed system can provide a precise and reliable measurement of the volume. The experiment to find the minimum volume detected by the developed system was performed in the 4th test and it was found to be 4 ml.

V. CONCLUSIONS

In conclusion, the saline monitoring system was successfully developed. This system is able to indicate the current saline volume in the bottle. When the level of the saline reaches the pre-defined critical volume, the medical staffs or caretakers will be notified by the alarm from the speaker and the alert message will be sent to the medical staffs via the application on the mobile phone using Bluetooth technology. This developed system can provide advantages on low cost, flexible use, convenient deployment and reliability. It can be reused for the next saline bottle. Medical staffs can easily observe the saline level from a distance.

ACKNOWLEDGMENT

The authors would like to thank the Faculty of Applied Science, King Mongkut's University of Technology North Bangkok (Grant# 6143106) for the financial support.

REFERENCES

[1] S. M. Park, J. Y. Kim, K. E. Ko, I. Jang, and K. Sim, "Real-Time Heart Rate Monitoring System based on Ring-Type Pulse Oximeter Sensor," Journal of Electrical Engineering & Technology, Vol. 8, issue 2, pp. 376–384, 2013.

[2] Y. Zhang, H. Liu, X. Su, P. Jiang, and D. Wei, "Remote Mobile Health Monitoring System Based on Smart Phone and Browser/Server Structure," Journal of Healthcare Engineering, Vol. 6, issue 4, pp. 717-737, 2015.

[3] Y. Geng, J. Chen, R. Fu, et al., "Enlighten wearable physiological monitoring systems: On–body RF characteristics based human motion classification using a support vector machine," IEEE Trans. on Mobile Computing, Vol. 99, pp. 1–15, 2015.

[4] M. M. Baig and H. Gholamhosseini, "Smart health monitoring systems: an overview of design and modeling," Journal of medical systems, Vol. 37, issue 2, pp. 1–14, 2013.

[5] S. Majumder, T. Mondal, and M. J. Deen, "Wearable Sensors for Remote Health Monitoring," Sensors (Basel), Vol. 17, issue 1, 2017.

[6] C. M. Chen, "Web-based remote human pulse monitoring system with intelligent data analysis for home health care," Expert Systems with Applications, Vol. 38, issue 3, pp. 2011-2019, 2011.

[7] Y. Zhang, S. Zhang and Y. Ji, G. Wu, "Intravenous infusion monitoring system based on WSN," in Wireless Sensor Network, Beijing, China, 2010.

[8] K. Vaishnav, N. Swamy, N. B. Haidarali and M. Patil, "IoT Based Saline Level Monitoring System," International Journal of Innovations & Advancement in Computer Science, Vol. 6, issue 10, pp. 65-69, 2017.

[9] M. Weiss, M. I. Hug, T. Neff, J. Fischer, "Syringe size and flow rate affect delivery from syringe pumps," Can J Anaesth, Vol. 47, issue 10, pp. 1031-1035, 2000.

[10] R. S. Murphy and S. J. Wilcox, "The link between intravenous multiple pump flow errors and infusion system mechanical compliance, " Anesth Analg., Vol. 110, issue 5, pp. 1297-1302, 2010.