

Short Text Message Based Infusion Fluid Level Monitoring System

Meilia Safitri¹, Helena Da Fonseca², Erika Loniza³

^{1, 2, 3}Department of Medical Electronics Technology, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

Email: ¹meilia.safitri@vokasi.umy.ac.id, ²helenadafonseca@gmail.com, ³erika@umy.ac.id,

*Corresponding Author

Abstract— Liquids or medications administered through intravenous systems (infusion) is necessary when a patient requires immediate medication or requires slowly and continuously administered medications. This method is considered adequate in certain situations; however, the liquids/medications administration of through infusion has a risk when the nurse is late in replacing intravenous fluid. In this study, the system was designed to monitor the fluid infusion level by utilizing a short text message system. This system will provide information when the infusion fluid level is at 50 ml, 20 ml, and 0 via SMS. Moreover, a buzzer is utilized that acts as an alarm when the reaching 20 ml level, and infusion fluid have not been replaced yet, and when the intravenous fluid does not drip. Infra-red sensors and photodiodes are used to detect intravenous droplets of fluid, which are then used to calculate fluids' volume. The system is controlled using an Atmega 328 microcontroller. SIM Modem 900 is used to send SMS. Based on tests carried out, infusion fluid level monitoring systems have excellent performance. The percentage of system errors when detecting fluid level infuse is 1,21%. The function of sending fluid level information through SMS also works well

Keywords— *Infusion fluid level, SIM 900, IR, photodiode*

I. INTRODUCTION

Infusion is a method of inserting liquids or medications through intravenous pathways or directly into the blood vessels [1]. Administration of fluid or medications with an intravenous route is carried out if the patient needs medicines that should be absorbed by the body very quickly or require medication or fluid at a constant rate within a specified period. In this condition, usually, the patient is no longer possible to be given oral medication, for example, patients with dehydration (lack of fluid), exposed to heart attack, stroke, or poisoned. In addition, giving fluids or drugs intravenously is also carried out in administering analgesic drugs [2], giving contrast fluids [3, 4], and can be used for sports athletes [5].

In the provision of infusion fluid to patients, several things should be considered, such as the liquids type, the liquids amount (volume), and their rates. The amount and rates of intravenous fluids administered into the patient's body depend on the condition of health, weight, and age of the patient. Improper administration of infusion fluid, such as too much or too little liquid, as well as a fluid rate that is too fast or too slow, will cause new problems for patients [6], especially for children [7] and elderly patients [8]. Besides,

supervision must also be performed during intravenous administration, especially in the case of intravenous replacement of fluids. The process of replacing the minimum level reached infusion fluid should be done quickly and precisely. Delays in the infusion fluid replacement can cause unwanted problems such as air embolism and blood clotting [9-11]. Air embolism can cause air bubbles inclusion into the heart or lungs, and the clotted blood can be sucked into the blood capillary vessels causing the blood flow to become obstructed. Air embolism on the human body is very dangerous. It can even lead patients to death [12-14].

In ideal conditions, administering the infusion fluid to the patient should be controlled and periodically monitored by the nurse. However, sometimes many patients often cause a nurse's negligence in overseeing the administration of infusion fluid to the patient. Recently, many systems to detect the level of intravenous fluids given to patients have been developed. In previous studies, the level of intravenous fluids entering the patient's body was measured using an analytical model [15], microwave TDR [16], learning-based computer vision [17,18], electrode [19], and optical sensor[20-23]. However, these studies have only recently developed a system for detecting fluid levels or the flow of intravenous fluids that have not yet reached the stage of providing information or warning to nurses in charge of patients. Infusion Fluid Level Monitoring system was once developed by Riskitasari et al. [6] using NRF24L01. The system has been successfully detected for an almost depleted infusion fluid level, but the use of NRF24L01 communication is still limited to 25 m and less effective when used in large and multilevel environments. The development of a monitoring system for intravenous fluids using radiofrequency has been carried out in [24,25]. The use of radio frequencies in the transmission of information is very susceptible to interference because frequency radio waves are quickly interrupted. Previous research has also developed a monitoring system for intravenous fluid levels using a wireless communication system [26-29]. The disadvantage of using this wireless communication system is the installation of a system that requires high costs and the complexity of the system being built.

In this study, the infusion fluid monitoring system on SMS Gate Away was developed. The use of SMS Gateway in information delivery will be beneficial since its ability reaching a wide area, and the signal used rarely get



interference [30]. The designed system will provide information to nurses when the infusion fluid level is at 50 ml, 20 ml, and 0 via SMS. Also, the system is also equipped with a buzzer that acts as an alarm when the infusion fluid reaching 20 ml level, has not been replaced, and when the intravenous fluid does not drip. Infra-red sensors and photodiodes are used to detect intravenous drip fluid, which is then used to calculate the volume of liquids. The system is controlled using an Atmega 328 microcontroller. SIM Modem 900 is used to send SMS.

II. MATERIAL AND METHODS

a. Intravenous infusion

Intravenous infusion, also known as drips, is a form of therapy by inserting fluids directly into the blood vessels. The route of intravenous administration can be in the form of a drug injection using a syringe or by the infusion method, which usually utilizes the earth's gravitational force. The use of the infusion method is the fastest way to administer fluids or drugs into the human body because they are given directly into the circulatory system. Giving fluids by infusion is usually done if the patient is not possible to be given oral medication and also if the patient needs prompt treatment.

Nowadays, we are facing the Industrial Revolution of 4.0 where the use of technology in everyday life has become more and more prominent and more, including technology application in medical equipment in the field. Medical equipment equipped with electronic systems can take more into account the precision and accuracy. One of the examples that have been developed is the nurse call. With nurse call, nurses will be facilitated because it can work more effectively and efficiently and can reduce the risk of negligence done by the nurse. Development of infusion fluid level monitoring system with long-distance nurse call.

In this study, an infusion fluid level monitoring system using Away Gate SMS and IR sensors and photodiodes was developed. The use of SMS Gateway in information delivery will be effective because it can reach a wide area, and the signal used rarely get interference. IR sensors and photodiodes are used to detect drip infusion fluid, where the level of infusion fluid is determined based on the number of droplets detected by the sensor. The drip count conversion is carried out by referring to the droplet factor that belongs to the infusion macro set i.e., 10, 15, and 20. The numbers on the infusion set of this macro are determined based on the diameter infusion hose used. It affects the infusion fluid rate in patients where the equation administers the rate of infusion fluid as,

$$\text{Fluid rate (ml / min)} = \frac{x \cdot A}{t} \quad (1)$$

with,

x = infusion fluid volume (ml)

A = drip factor (10, 15, or 20)

t = time (minutes)

b. System Design

The design of the infusion fluid level monitoring system consisted of hardware design and software design. The hardware design is how the system can be realized using the

necessary tools. The system-designed block Diagram is shown in Figure 1.

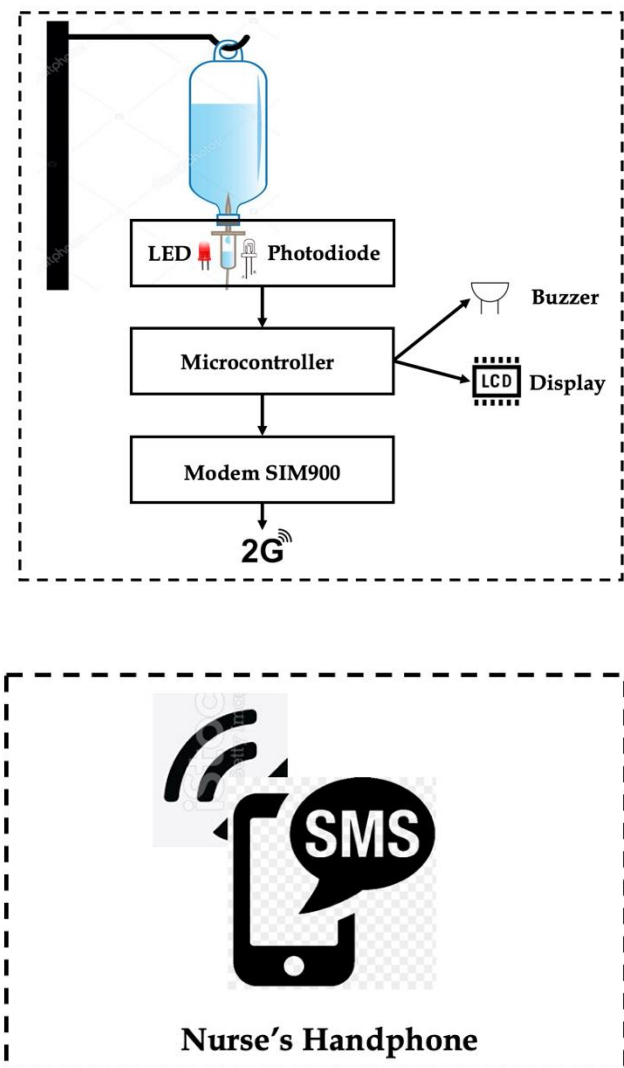


Fig. 1. System Design Block Diagram

At the hardware design of the infusion fluid level monitoring system, lithium 3,7 Volt DC batteries are used as the entire circuit voltage source. The batteries used then recharged using the charger circuit and in the battery-operated, and there is a step-up module that serves to increase the battery voltage to 5 Volt DC. IR Sensors (InfraRed) and photodiodes then working continuously to detect drip infusion fluid. Photodiodes detect drip infusion fluid, and the sensor will transmit the signal to Atmega The microcontroller will then process the signals provided by the IR sensors and the photodiode. After the data finishes processing, the microcontroller will send the inputs to display on the LCD, input to the buzzer, and SIM module 900. The SIM 900 module will then transmit the processed data to the nurse's phone.

In order to make the designed system design work as desired, the design was arranged as shown in Figure 2.

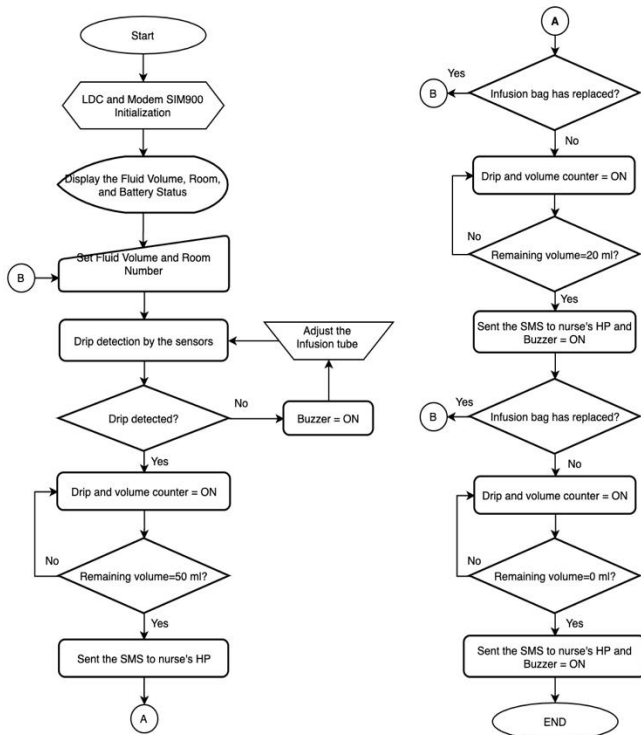


Fig. 2. System flowchart

When the appliance is switched On (by pressing the On/OFF button), the LCD and SIM 900 will initialize in preparation for the next process. The LCD will then display the initial volume, the room, and the Batterie status. Next, the user can perform the desired volume and room reset. Once the appliance is run, the device detects drip infusion fluid, if drip infusion fluid is not detected, then the buzzer will light up, and the nurse or user will receive a notification that the infusion fluid does not drip. After the first drip is detected, the appliance will send the nurse's information regarding the volume and room where the infusion fluid is placed. Afterward, fluid infusion volume through drip fluid amount calculation will be carried out. When the remaining infusion fluid stays 50 ml, the device will inform the nurse via SMS. If the nurse has replaced the infusion fluid, the device will repeat the process from scratch. However, if the infusion fluid has not been replaced, the appliance will continue the calculation of fluid infusion volume. When the remaining fluid reaches 20 ml, the instrument will again provide information to the nurse, and the buzzer will remain active. If the infusion fluid has not been replaced, the calculation of the volume will continue until the rest of the infusion fluid is depleted, and then the appliance will inform the nurse, and the buzzer will continue active.

III. RESULT AND DISCUSSION

To determine if the designed system can work under the desired and excellent performance, several tests have been carried out, namely, voltage sensor when there are droplets and no droplets testing, the volume of infusion fluid testing, and SMS delivery to the phone nurse testing. The following is the result of the tests..

a. Sensor Voltage Test

The first test is the sensor voltage testing; this test was done by measuring the photodiode sensor's output voltage when infusion fluid drip and when the infusion fluid did not drip. The test aimed to determine the voltage limit to be processed in Atmega 328 to detect drip infusion fluid. The data will then be processed to calculate the volume of infusion fluid that has been absorbed by the body. The voltage testing results in photodiodes sensors indicated by table 1 as follows.

TABLE I. OUTPUT SENSOR VOLTAGE TEST RESULT

No	Fluid drip voltage	Fluid not drip voltage
1	4.50 V	4.54 V
2	4.52 V	4.54 V
3	4.51 V	4.54 V
4	4.45 V	4.54 V
5	4.50 V	4.54 V
6	4.44 V	4.54 V
7	4.48 V	4.54 V
8	4.48 V	4.54 V
9	4.51 V	4.54 V
10	4.51 V	4.54 V
	$\bar{x} = 4.49$ volt	$\bar{x} = 4,54$ volt

Based on the test results indicated by table 1. it appeared that when the sensor detects a drip infusion, the resulting average voltage is 4,49 volts, and the sensor output voltage varies from 4,44 volts to 4,52 volts. It was different from the condition of photodiodes sensors that do not detect drip infusion where the resulting output voltage is constant in the number of 4,54 volts.

b. Infusion Volume Test

The second test was testing the volume of the infusion fluid. The purpose of this test was to find out if the volume calculation algorithm of an infusion fluid designed to run well. This test was done by comparing the volume of fluid indicated on the infusion bottle with the volume indicated on the LCD. The results of the infusion fluid volume test are shown in table 2.

TABLE II. INFUSION FLUID VOLUME TEST RESULT

No	On-bottle display (ml)	On LCD display (ml)	Absolute error (ml)	Error percentage (%)
1	500	500	0	0
2	450	450.90	0.9	0.2
3	400	400.80	0.8	0.2
4	350	350.70	0.7	2.45
5	300	300.70	0.7	2.1
6	250	250.85	0.85	2.12
7	200	200.85	0.85	1.7
8	150	150.90	0.9	1.35
9	100	100.85	0.85	0.85
	Mean		0.72	1.21

Table 2. indicates that a small error percentage value is 0, and the most significant error percentage is 2,45%, with a percent error mean of 1,21%. It suggests that the designed device has worked as desired and has an excellent performance, proven by the measurement accuracy of more than 90%.

c. SMS Delivery Test

The last test was testing the SMS sending to the nurse's phone. This test aimed to determine if the SIM 900 system has been able to send SMS in the specified conditions. The result of this SMS delivery test is demonstrated by Table 3.

^aTABLE III. SMS DELIVERY TEST RESULTS

No	Fluid conditions	Description
1	500 ml	Sms sent
2	50 ml	Sms sent
3	20 ml	Sms sent
4	0 ml	Sms sent
5	No drip	Sms sent

Based on the data shown in table 3. it appears that the designed system has been able to send SMS on the phone on the specified conditions. An example of SMS sent to mobile is shown by Figure 3.

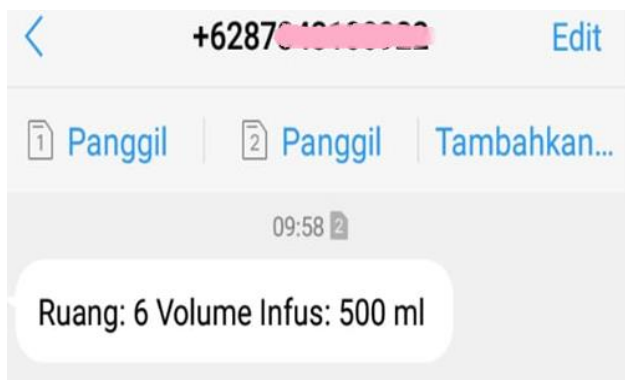


Fig. 3. The result of sending SMS to mobile

Based on the tests that have been conducted, the designed device demonstrated the effectiveness of the use of an SMS based system for monitoring the level of fluid infusion. This system utilizes LED and Photodiode sensors to detect every drop of intravenous fluid that will enter the patient's body. Each detected drop will then be counted and converted into milliliters. Table 2 shows the comparison between the results of the calculation of the volume of fluids by the system designed with the actual volume listed on the infusion fluid bag. The results of this intravenous fluid volume test show excellent results with an accuracy of about 98%. This indicates that the designed system has succeeded in establishing the desired performance. The test results showed that the SIM900 Modem successfully sent short messages to the responsible nurse's phone. Table 3 shows that when the system detects the first drop, it has succeeded in sending SMS. Likewise, at the time, the remaining fluid volume

remains 50 ml, and for 20 ml, 0 ml device has also managed to provide a buzzer warning.

IV. CONCLUSIONS

Based on the results of the testing of infusion fluid level monitoring tools that have been done, it can be concluded that the monitoring system of infusion fluid level has been designed to successfully detect the fluid infusion level well with the percentage of errors in volume measurement is 1,21%. This device has also managed to provide a buzzer warning and send the information in the form of SMS messages to the nurse when infusion liquid 500ml, 50 ml, 20 ml, 0 ml, and when the infusion fluid does not drip.

For further research development, it is advisable to add a bubble detector in infusion fluid, and the monitoring system can be developed using an Android application that comes with patient bed number information.

REFERENCES

- [1] C. E. Peeler, C. M. Villani, M. G. Fiorello, H. J. Lee, M. L. Subramanian, and G. Oral versus Intravenous Sedation Study, "Patient Satisfaction with Oral versus Intravenous Sedation for Cataract Surgery: A Randomized Clinical Trial," *Ophthalmology*, vol. 126, no. 9, pp. 1212-1218, Sep 2019, doi: 10.1016/j.ophtha.2019.04.022.
- [2] T. J. Gan *et al.*, "The shortened infusion time of intravenous ibuprofen, part 2: a multicenter, open-label, surgical surveillance trial to evaluate safety," *Clin Ther*, vol. 37, no. 2, pp. 368-75, Feb 1 2015, doi: 10.1016/j.clinthera.2014.12.006.
- [3] T. Chan, B. McGillen, and K. McGillen, "Inversion of excreted intravenous contrast-fluid levels in the urinary bladder on computed tomography," *Radiol Case Rep*, vol. 11, no. 4, pp. 318-322, Dec 2016, doi: 10.1016/j.radcr.2016.07.004.
- [4] R. Solomon, "Hydration: Intravenous and Oral: Approaches, Principals, and Differing Regimens: Is It What Goes in or What Comes Out That Is Important?," *Interv Cardiol Clin*, vol. 9, no. 3, pp. 385-393, Jul 2020, doi: 10.1016/j.iccl.2020.02.009.
- [5] S. Pomroy, G. Lovell, D. Hughes, and N. Vlahovich, "Intravenous fluids and their use in sport: A position statement from the Australian Institute of Sport," *J Sci Med Sport*, vol. 23, no. 4, pp. 322-328, Apr 2020, doi: 10.1016/j.jsams.2019.10.020.
- [6] D. Vena and A. Yadollahi, "The effect of fluid overload by saline infusion on heart rate variability in men during sleep," in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 25-29 Aug. 2015 2015, pp. 2047-2050, doi: 10.1109/EMBC.2015.7318789.
- [7] A. Lander, "Intravenous fluid and electrolyte management in children and young people," *Surgery (Oxford)*, vol. 37, no. 4, pp. 189-194, 2019, doi: 10.1016/j.mpsur.2019.02.002.
- [8] E. Ferenczi, S. S. Datta, and A. Chopada, "Intravenous fluid administration in elderly patients at a London hospital: a two-part audit encompassing ward-based fluid monitoring and prescribing practice by doctors," *Int J Surg*, vol. 5, no. 6, pp. 408-12, Dec 2007, doi: 10.1016/j.ijssu.2007.05.012.
- [9] A. Brodbeck, P. Bothma, and J. Pease, "Venous air embolism: ultrasonographic diagnosis and treatment with hyperbaric oxygen therapy," *Br J Anaesth*, vol. 121, no. 6, pp. 1215-1217, Dec 2018, doi: 10.1016/j.bja.2018.09.003.
- [10] M. León Ruiz, J. Benito-León, M. Á. García-Soldevilla, E. García-Albea Ristol, and J. A. Arranz Caso, "Clarifications to

- "First described case of coma triggered by retrograde venous air embolism: an exceptional but potentially life-threatening situation", *Neurología (English Edition)*, vol. 35, no. 7, pp. 516-517, 2020, doi: 10.1016/j.nrleng.2018.12.015.
- [11] R. C. Reu, W. Friesdorf, and S. König, "A.90 Experimental study on the amount of venous air embolism through wide bore catheters and parallel infusion," *British Journal of Anaesthesia*, vol. 76, 1996, doi: 10.1016/s0007-0912(18)30945-0.
- [12] S. Hadjadj, D. d. Val, J. Beaudoin, J. Rodés-Cabau, and J.-M. Paradis, "To take one's breath away: Echocardiography-guided aspiration of an air embolism during a MitraClip procedure," *CJC Open*, 2020, doi: 10.1016/j.cjco.2020.08.010.
- [13] A. Morales-Cardenas, J. Kosiuk, and A. Semionov, "Pulmonary air embolism associated with proximal bland thrombus," *Radiol Case Rep*, vol. 15, no. 6, pp. 680-682, Jun 2020, doi: 10.1016/j.radcr.2020.02.027.
- [14] E. Uysal, N. Alkan, and B. Cam, "A life-threatening condition: The pulmonary artery air embolism," *Turk J Emerg Med*, vol. 19, no. 4, pp. 157-159, Oct 2019, doi: 10.1016/j.tjem.2019.09.001.
- [15] F. Yang, K. Chen, and Z. Feng, "Analytical model of initial fluid infusion by a microneedle drug delivery system," in *2011 4th International Conference on Biomedical Engineering and Informatics (BMEI)*, 15-17 Oct. 2011 2011, vol. 2, pp. 913-917, doi: 10.1109/BMEI.2011.6098420.
- [16] A. Cataldo, G. Cannazza, N. Giaquinto, A. Trotta, and G. Andria, "Microwave TDR for Real-Time Control of Intravenous Drip Infusions," *IEEE Transactions on Instrumentation and Measurement*, vol. 61, no. 7, pp. 1866-1873, 2012, doi: 10.1109/tim.2012.2192346.
- [17] N. Giaquinto, M. Scarpetta, M. A. Ragolia, and P. Pappalardi, "Real-time drip infusion monitoring through a computer vision system," in *2020 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, 1 June-1 July 2020 2020, pp. 1-5, doi: 10.1109/MeMeA49120.2020.9137359.
- [18] R. Dudde, V. Thomas, G. Piechotta, and R. Hintsche, "Computer-aided continuous drug infusion: setup and test of a mobile closed-loop system for the continuous automated infusion of insulin," *IEEE Transactions on Information Technology in Biomedicine*, vol. 10, no. 2, pp. 395-402, 2006, doi: 10.1109/TITB.2006.864477.
- [19] H. Ogawa, H. Maki, S. Tsukamoto, Y. Yonezawa, H. Amano, and W. M. Caldwell, "A new drip infusion solution monitoring system with a free-flow detection function," in *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology*, 31 Aug.-4 Sept. 2010 2010, pp. 1214-1217, doi: 10.1109/IEMBS.2010.5626449.
- [20] M. McLellan, A. Poulton, and O. Hung, "The clinical utility of the Fluid Intravenous Alert monitor," *J Clin Anesth*, vol. 35, pp. 293-294, Dec 2016, doi: 10.1016/j.jclinane.2016.09.008.
- [21] S. S. Alagundagi, K. Pasala, and M. Arora, "Opto-electronic system for intravenous infusion monitoring," in *2018 10th International Conference on Communication Systems & Networks (COMSNETS)*, 3-7 Jan. 2018 2018, pp. 688-692, doi: 10.1109/COMSNETS.2018.8328296.
- [22] M. I. Ali, "Designing a Low-Cost and Portable Infusion Pump," in *2019 4th International Conference on Emerging Trends in Engineering, Sciences and Technology (ICEEST)*, 10-11 Dec. 2019 2019, pp. 1-4, doi: 10.1109/ICEEST48626.2019.8981680.
- [23] M. K. Bhavasaar, M. Nithya, R. Praveena, N. S. Bhuvanewari, and T. Kalaiselvi, "Automated intravenous fluid monitoring and alerting system," in *2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR)*, 15-16 July 2016 2016, pp. 77-80, doi: 10.1109/TIAR.2016.7801217.
- [24] D. J. Kim *et al.*, "Design a wireless capacitive sensor detection system with power line communication for liquid volume of intravenous drip measurement," in *Proceedings of 2012 IEEE-EMBS International Conference on Biomedical and Health Informatics*, 5-7 Jan. 2012 2012, pp. 269-272, doi: 10.1109/BHI.2012.6211563.
- [25] H. Nakajima and M. Takahashi, "Monitoring system for removing IV needles using RFID technology," in *2014 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC)*, 3-9 Aug. 2014 2014, pp. 111-112, doi: 10.1109/APWC.2014.6905529.
- [26] M. V. Caya, M. U. Cosindad, N. I. Marcelo, J. N. M. Santos, and J. L. Torres, "Design and Implementation of an Intravenous Infusion Control and Monitoring System," in *2019 IEEE International Conference on Consumer Electronics - Asia (ICCE-Asia)*, 12-14 June 2019 2019, pp. 68-72, doi: 10.1109/ICCE-Asia46551.2019.8941599.
- [27] A. W. Setiawan, N. Yenas, and D. Welsan, "Design and Realization of Low-Cost Wireless Remote Infusion Monitoring System," in *2018 International Seminar on Application for Technology of Information and Communication*, 21-22 Sept. 2018 2018, pp. 151-154, doi: 10.1109/ISEMANTIC.2018.8549820.
- [28] Y. Zhang, S. F. Zhang, Y. Ji, and G. X. Wu, "Wireless sensor network-enabled intravenous infusion monitoring," *IET Wireless Sensor Systems*, vol. 1, no. 4, pp. 241-247, 2011, doi: 10.1049/iet-wss.2011.0031.
- [29] P. P. Ray and N. Thapa, "A systematic review on real-time automated measurement of IV fluid level: Status and challenges," *Measurement*, vol. 129, pp. 343-348, 2018, doi: 10.1016/j.measurement.2018.07.046.
- [30] H. Rashid, S. Shekha, S. M. T. Reza, I. U. Ahmed, Q. Newaz, and M. Rasheduzzaman, "A low cost automated fluid control device using smart phone for medical application," in *2017 International Conference on Electrical, Computer and Communication Engineering (ECCE)*, 16-18 Feb. 2017 2017, pp. 809-814, doi: 10.1109/ECACE.2017.7913014.