Journal of Experimental and Applied Physics
Journal Homepage: jeap.ppj.unp.ac.id
Vol. 2, No. 1, March 2024.
ISSN (Print): 2988-0378 ISSN (Online): 2987-9256

Design And Implementation of Intravenous Infusion Monitoring System Based on Wireless Sensor Network with Smartphone Display

Teguh Afrianda[1], Yulkifli[1,*] , Yohandri[1], Aulia Asman[2]

[1] *Department of Physics, Padang State Univercity, Padang 25131, Indonesia*
[2] *Department of Nursing, Padang State University, Padang 25131, Indonesia*

Article History
Received : February, 9th 2024
Revised : March, 1st 2024
Accepted : March 31st, 2024
Published : March 31st, 2024

DOI:
https://doi.org/10.24036/jeap.v2i1.42

Corresponding Author
*Author Name: Yulkifli
Email: yulkifliamir@gmail.com

Abstract: This research introduces a Wireless Sensor Network (WSN) based infusion monitoring system utilizing Internet of Things (IoT) technology. Infusion management is critical in healthcare, but manual supervision often lacks accuracy and control. Through the use of optocoupler and load cell sensors, this system enables automated calculation of the infusion drop rate per minute and evaluation of the remaining fluid percentage. In this study, tests were conducted using optocoupler sensors to calculate the drop rate per minute and load cell sensors to measure the remaining fluid percentage. Measurement results are monitored via smartphone, allowing healthcare professionals easy and rapid access to data. Furthermore, the innovation of this system lies in the application of Internet of Things (IoT) technology, enabling remote control through Wireless Sensor Network (WSN). Thus, one nurse can oversee multiple infusions using just one smartphone. The testing results demonstrate a high level of accuracy, with an average precision rate of 97% for drop rate measurements and 93% for the remaining fluid percentage measurements. This system offers an efficient and controlled solution for infusion fluid management, ensuring optimal healthcare services for patients. By integrating IoT and WSN technologies, this research paves the way for the development of more advanced and connected infusion monitoring systems, supporting enhanced patient care in the era of globalized healthcare.

Keywords: Infus, IoT, Optocoupler, Smartphone WSN.

How to cite:
T. Afrianda, A.Z. Yulkifli, Yohandri and A. Asman, 2024, Design And Implementation of Intravenous Infusion Monitoring System Based on Wireless Sensor Network with Smartphone Display,
Journal of Experimental and Applied Physics, Vol.1, No.1, page 106-117.

1. Introduction

In the realm of healthcare, the role of globalization is crucial in inspiring scientific progress, change, and evolution. Furthermore, there is no denying that the continuous advancement of medical technology, especially in the application of the Internet of Things (IoT), is a key factor in improving the efficiency and accuracy of medical services[1]. In some healthcare settings, there is a pressing need for technological advancements to promote new innovations in their development. Medical professionals are therefore expected to utilize this technology to the fullest in order to improve the quality of health services for the entire community [2]. Therefore, the field of Electronics and Instrumentation has become a serious and compelling focus among the new generation of technology designers [3]. One of the challenges in the healthcare sector is the continued manual administration of intravenous infusions. Issues such as blockages or interruptions in flow are common, and in some cases, even the entry of blood into the infusion line due to depletion of the infusion fluid occurs without the awareness of medical staff. If such incidents occur, patients may experience dehydration or fluid deficiency if not promptly addressed [4]. Intravenous fluid infusion is a specialized type of injection used to assist the body in replenishing lost fluids and nutrients [5].

One of the methods of administering fluids intravenously to fulfill the patient's requirements for fluids, electrolytes, medication, and nutrition is through an infusion [6]. The healing process of patients significantly relies on the controlled and regulated administration of intravenous fluids by medical professionals. Healthcare services in Indonesian community health centers are more concentrated in the western regions compared to the central and eastern parts of the country, based on workforce distribution. This concentration can impede the growth of healthcare services aimed at providing equitable and high-quality healthcare to the entire population of Indonesia[7].

Previous research [8] has developed an IoT-based infusion monitoring device with smartphone display. With this device, we can remotely monitor the infusion status using a smartphone via Thingspeak. However, there is a limitation in this research: we can only monitor one patient with one smartphone. This limitation poses a challenge, especially when the number of patients exceeds the available nurses in a hospital, as typically, each nurse uses only one smartphone. To address this limitation, I innovated by introducing a system that mitigates the drawbacks of the previous research. By integrating a Wireless Sensor Network (WSN), one nurse can control multiple patient infusions using a single smartphone. This innovation proves to be efficient, particularly during surges in patient numbers at a hospital, thereby enhancing healthcare services for the patients [9]

In the context of this research, counting the number of infusion drips per minute is done using an optocoupler sensor. This sensor operates by detecting objects and measuring how long the object obstructs the light transmitted by the sensor. The structure of the optocoupler sensor involves a light source and a light detector that collaborate in this function [10]. In addition to calculating the number of drops per minute, the automatic infusion fluid monitoring device is also capable of evaluating the remaining percentage of infusion fluid.

The concept of the Internet of Things (IoT) endeavors to optimize the advantages of internet connectivity for facilitating seamless data exchange among various devices and centralized systems [11] Through the concept of the "Internet of Things," any network-connected object can autonomously transmit data without human intervention, thereby augmenting efficiency in medical services with the integration of this technology [12] The Internet of Things (IoT) is a comprehensive system that integrates devices, actuators, sensors, communication protocols, and applications, which autonomously exchange data and commands across networks to deliver intelligent services [13]. In this research, the smartphone functions as a display screen that gathers specific data for analysis and storage. Besides serving as a communication device, the smartphone also acts as a measurement system [14]. This research stands out for its utilization of Internet of Things (IoT) technology and Wireless Sensor Network (WSN) to facilitate remote monitoring and control in infusion monitoring systems. By integrating optocoupler and load cell sensors, the system achieves a high level of precision in measuring drop rates and remaining fluid percentages, with an average precision rate of 97% and 93% respectively. Its primary advantage resides in enhanced data accessibility, enabling healthcare professionals to efficiently and promptly retrieve monitoring information via their smartphones [15]. As a result, this research not only enables more efficient supervision, but also reduces the risk of human error and improves safety in infusion management [16]. This marks a significant step forward in enhancing the quality of patient healthcare services and paves the way for the development of more advanced and interconnected infusion monitoring systems in the future.

2. Materials and Method

This research is an engineering study, where scientific knowledge is combined in the design to achieve specific objectives. The research phase can be observed in Figure 1. Some of the procedures carried out in the research include Analysis and requirements definition, tool design (Ideas and task clarity), Implementation Design, Design validation, and finally the tool evaluation stage.

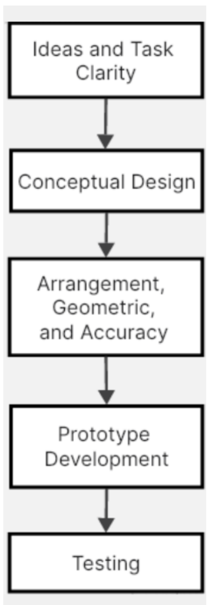

Figure 1. Engineering research phase.

Figure 1 represents the stages of engineering research involving relatively new elements [15]. It includes ideation, conceptual design, geometric and functional arrangement, detailed design, prototype/model development, and finally, the testing phase. In this study, the design of a wireless sensor network-based infusion monitoring system with smartphone display will be produced. The tools and materials utilized in this research encompass a personal computer (PC) for programming in Arduino IDE, which is then uploaded to Node MCU. Additionally, various electronic components such as optocouplers, load cells, and servo motors are employed.

The infusion fluid monitoring system is designed with careful consideration of both hardware and software aspects. Software design plays a crucial role as instructions for the hardware to execute its tasks efficiently. Meanwhile, hardware refers to the physical components of the system, explaining the physical elements involved in monitoring the infusion fluid. Figure 2 illustrates the detailed hardware components of the infusion fluid monitoring system. In this phase, the primary focus is to ensure seamless integration between hardware and software components, aiming for accurate and reliable infusion fluid monitoring.

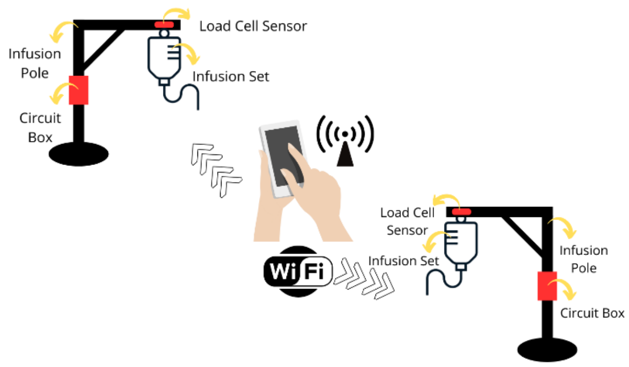

Figure 2. Design of the Hardware System for Infusion Monitoring Based on WSN.

Figure 2 display a circuit box contains Node ESP32 connected to a load cell, optocoupler, and servo motor. The optocoupler sensor is installed on the infusion tube to detect the drops of the infusion, enabling the calculation of the infusion drops per minute. The servo motor is attached to the infusion tube and connected to the circuit. Additionally, the infusion bottle is suspended on the load cell sensor, acting as a load measured by the sensor to monitor the remaining fluid level in the infusion bottle.

To facilitate the operation of the designed hardware and ensure all components are connected, the sensors are programmed using the Arduino programming language in the Arduino IDE application. This program will connect to an available WiFi network. Once successfully connected, the data will be transmitted to the cloud platform, Thingspeak. At this stage, the App Inventor application will be programmed to display monitoring data, such as the number of drops per minute and the remaining infusion fluid level, on the smartphone screen. The software design process using App Inventor can be observed in detail in Figure 3.

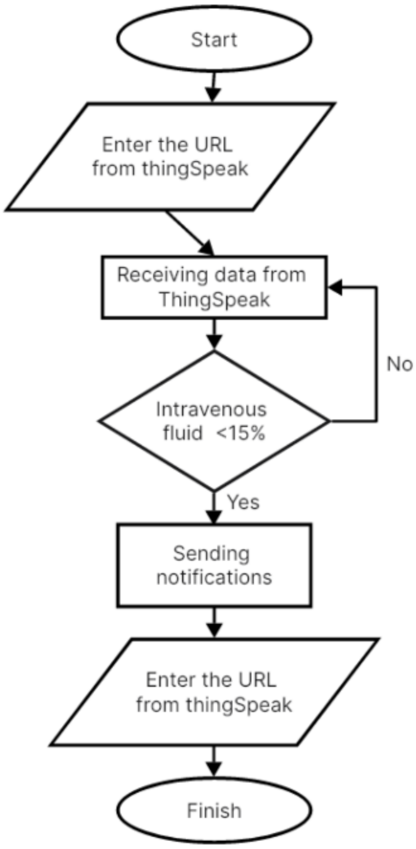

Figure 3. Flowchart software desain.

Figure 3 illustrates the flow of the App Inventor software. This flowchart illustrates the process of retrieving data from ThingSpeak, checking intravenous fluid levels, and sending notifications. First, the user enters the URL of ThingSpeak, an IoT platform that enables real-time collection, analysis, and visualization of sensor data. This URL connects to the data sent by sensors or devices connected to ThingSpeak. Next, the system receives data from ThingSpeak that may contain information about the intravenous fluid, such as level or volume. Then, there is a step of checking the "Intravenous fluid <15%" condition. If the data indicates that the intravenous fluid is less than 15%, the system proceeds to the next step. However, if the condition is not met, the system will return to the "Enter URL from ThingSpeak" step to update the data. Finally, if the condition "Intravenous fluid <15%" is met, the system will send a notification in the form of a telegram message to the user or medical staff.

3. Results and Discussion

The result of the design conducted is a monitoring system for infusion based on Wireless Sensor Network with a user interface accessible through a smartphone. This device is capable of calculating the proportion of remaining infusion fluid and the infusion drops rate per minute. The measurement results will be displayed directly on the user's smartphone screen. The mechanical design of the infusion monitoring system can be observed in Figure 4.

Figure 4. Infusion Fluid Monitoring System based on WSN.

Figure 4 shows the design of a fluid infusion monitoring system that utilizes the latest technology in the fields of electronics and sensorics. This system's main aim is to carry out precise calculations of the number of infusion drops per minute and accurately measure the remaining infusion fluid. To achieve this target, the system uses two core components, namely a load cell sensor and an optocoupler. The use of the ESP32 Node MCU as the brain of the system is considered crucial because this device is not only responsible for careful data processing, but also a bridge between electronic circuits and smart devices, especially smartphones. The integration of other components such as servo motor, optocoupler, and load cell sensor with the ESP32 Node MCU allows the system to operate with efficient synergy. For further explanation regarding the structure and interaction of these components, users are invited to refer to Figure 5.

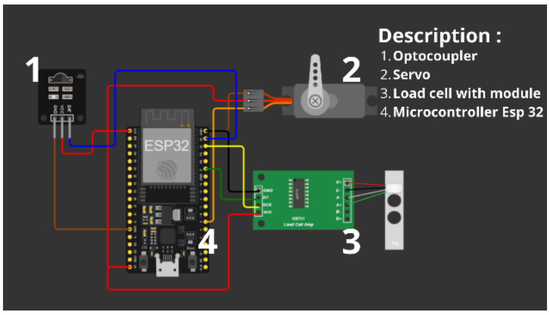

Figure 5. Interaction of each component.

Figure 5 illustrates the arrangement of components in the ESP32 microcontroller in detail. This diagram highlights the connections established between the ESP32 MCU Node and the various electronic elements in the system, including the servo motor, optocoupler, and load cell sensor. This arrangement has been carefully designed to ensure optimal system function and performance in the fluid infusion monitoring process. For a more complete experience of the user interface on the smartphone connected to the system, it is recommended to refer to Figure 6.

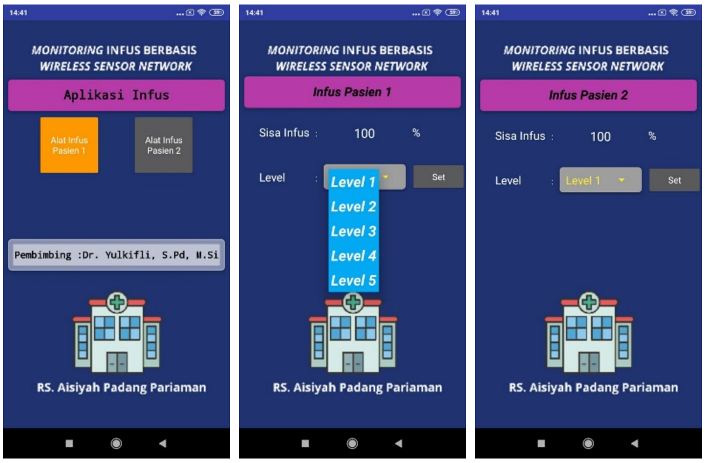

Figure 6. Infusion Monitoring Interface WSN on Smartphone.

Figure 6 shows the user interface of the Wireless Sensor Network (WSN)-based infusion monitoring system on a smartphone device. The system has servo motion control functions to adjust the tube gap width and set the drip rate per minute. In addition, the system provides information on the percentage of remaining infusion fluid, which is obtained through measurement with a load cell sensor. Tests were conducted to evaluate the sensor output and its accuracy. When the percentage of remaining infusion fluid exceeds the 15% limit, an automatic warning notification will appear on the smartphone, informing the user that the infusion is running low and a replacement with a new infusion needs to be prepared. This test is intended to assess the extent of the tool's success in achieving the research objectives. The test results of the load cell sensor show satisfactory accuracy in measuring the weight of the infusion compared to the actual value. For more detailed data regarding the test results of each load cell sensor, please refer to Table 1 and Table 2. Thus, the user interface in Figure 6 not only provides efficient control and monitoring, but also supports the early warning aspect and overall performance evaluation of the device.

Table 1. Accuracy of Infusion Percentage for Patient 1

Massa (gr)	Measurable	Calculated	Error	% Precision
500	100	100	0 %	100 %
450	91	90	1 %	99 %
400	81	80	1 %	99 %
350	71	70	1 %	99 %
300	62	60	3 %	97 %
250	52	50	4 %	96 %
200	43	40	8 %	93 %
150	32	30	7 %	93 %
100	23	20	15 %	85 %
50	11	10	10 %	90 %
	Average		5 %	95 %

Table 2. Accuracy of Infusion Percentage for Patient 2

Massa (gr)	Measurable	Calculated	Error	% Precision
500	100	100	0 %	100 %
450	90	90	0 %	100 %
400	81	80	1 %	99 %
350	73	70	4 %	96 %
300	62	60	3 %	97 %
250	52	50	4 %	96 %
200	41	40	3 %	98 %
150	33	30	10 %	90 %
100	23	20	15 %	85 %
50	13	10	30 %	70 %
	Average		5 %	93 %

The Table 1 data provided is the result of measuring the mass (grams) and measurable value of a system. In this analysis, there are several aspects to consider to understand the overall picture of this data. The majority of the measurement results show a high level of accuracy, with most of the measurable values being close to the expected (calculated) values. For example, in the case with a mass of 500 grams, the measurement results presented perfect accuracy with a percentage error of 0%, demonstrating the reliability of the system in measuring the desired value. However, there are some cases where there are deviations between the measured and expected values, which are reflected in different percentage errors. For example, in the case with a mass of 100 grams, there was a percentage error of 15%, indicating inaccuracies in the measurement at lower values of weight.

It should also be noted that there are variations in the precision (% precision) from one measurement to another. Although the average precision is 95%, there are some cases where the precision is lower, such as the case with a mass of 200 grams which has a precision of 93%. This points to fluctuations in the consistency of the measurement results over time or may depend on different operational conditions. Thus, although in general the measurement results show a high level of accuracy, it is necessary to identify and understand the causes of the inaccuracies and fluctuations that occur. Further analysis can help to identify the factors that contribute to measurement results that do not meet expectations, allowing for system improvements and increased measurement accuracy and consistency in the future.

It should also be noted that there are variations in the precision (% precision) from one measurement to another. Although the average precision is 95%, there are some cases where the precision is lower, such as the case with a mass of 200 grams which has a precision of 93%. This points to fluctuations in the consistency of the measurement results over time or may depend on different operational conditions. Thus, although in general the measurement results show a high level of accuracy, it is necessary to identify and understand the causes of the inaccuracies and fluctuations that occur. Further analysis can help to identify the factors that contribute to measurement results that do not meet expectations, allowing for system improvements and increased measurement accuracy and consistency in the future.

Based on analysis Tables 2, a similarly high level of precision is observed, with an average difference between measured and expected values of only 1-4%. However, there are some values that show larger variations, especially in measurements with masses of 150 gr and 50 gr. This suggests that there are factors influencing inaccuracies in measurements at these points, which require further investigation. Although the average error rate in this analysis is also 5%, it's important to note that there is an outlier in the measurement with a mass of 50 gr, where the error reaches 30%. This indicates the possibility of factors affecting inaccuracies in measurements at that point.

From the comparison of the two analyses, it can be concluded that both show a high level of precision overall. However, the first analysis tends to be more consistent in producing accurate results, while the second analysis shows slightly larger variations in measurement results. There are also differences in the response to various infusion masses, where the second analysis exhibits an outlier in the measurement with a mass of 50 gr. This underscores the importance of further evaluation to identify factors affecting inaccuracies in measurements in the second data set. Nonetheless, both analyses still yield a similar average error rate of 5%, indicating that overall, they remain reliable in measuring the drop rate and remaining fluid percentage in the infusion. The accuracy testing results for the number of drops per minute from the optocoupler sensors for each device can be found in Table 3 and Table 4.

Table 3. Accuracy of Infusion Percentage for Patient 1

Set Poin Input	Measurable	Error	Acuracy
20	20	0 %	100 %
20	20	0 %	100 %
20	21	5 %	95 %
20	22	9 %	90 %
20	20	0 %	100 %
20	19	5 %	95 %
20	21	5 %	95 %
20	19	5 %	95 %
20	20	0 %	100 %
20	20	0 %	100 %
Average		3 %	97 %

Table 4. Accuracy of Infusion Percentage for Patient 2

Set Poin Input	Measurable	Error	Acuracy
20	20	0 %	100 %
20	19	5 %	95 %
20	20	5 %	100 %
20	21	9 %	95 %
20	20	0 %	100 %
20	19	5 %	95 %
20	21	5 %	95 %
20	19	5 %	95 %
20	20	0 %	100 %
20	20	0 %	100 %
Average		3 %	98 %

After carefully examining Table 3, a comprehensive set of measurements regarding the infusion fluid monitoring system was revealed, which included input set points, actual measured values, percentage error, and resulting accuracy. The analysis illustrated a spectrum of accuracy levels across the data set, with the majority of measurements showing high levels of accuracy, mainly reaching 100%. However, minor deviations were noted in certain cases, where the percentage error fluctuated between 5% to 9%, resulting in accuracy levels of 90% and 95%. These variations can be caused by a variety of factors, such as sensor calibration, environmental conditions, or small system fluctuations. However, despite these slight discrepancies, the average accuracy of the dataset remained commendable at 97%, indicating consistent and reliable performance of the infusion fluid monitoring system as a whole.

Based on analysis Tables 4, the second dataset also shows a similar pattern to the first, with the majority of cases achieving very high accuracy (100%) and only a few cases with errors (5-9%). However, the average accuracy of this dataset is slightly higher, at 98%. This suggests that the second dataset performs slightly better than the first in terms of predicting and measuring desired values.

When considering the implications of the difference in accuracy rates between Data 3 and Data 4 in the context of monitoring the infusion process, a more in-depth assessment of its effect on medical practice is required. The higher accuracy rate of Data 4, which reaches 98% on average, provides stronger confidence in the measurement results. This confidence is especially important in sensitive medical situations where quick and accurate decisions are required to determine the right treatment for patients. In the supervision of infusion processes, where the dosage of drugs and intravenous fluids can have a direct impact on the patient's health, the reliability of the monitoring system is critical. The higher accuracy rate of Data 4 gives medical practitioners additional confidence in monitoring and managing the infusion process appropriately.

However, while Data 4 performs better in terms of accuracy, this does not mean that Data 3 does not have similar value. A careful analysis of both datasets can provide valuable insights in understanding the factors that affect accuracy and consistency in measurements. Data 3, despite having some measurements with lower accuracy, still performed well overall with an average accuracy of 97%. This signifies that the monitoring system associated with Data 3 remains reliable in use, especially if factors causing variations in accuracy can be identified and addressed correctly.

In this context, it is important to combine qualitative judgment with quantitative data in evaluating infusion fluid monitoring systems. In addition to considering accuracy rates, factors such as system reliability, ease of use, and data availability should also be considered. By understanding thorough the performance and characteristics of each dataset, medical practitioners can make more informed decisions in selecting and implementing monitoring systems that suit medical and clinical needs.

4. Conclusion

Based on the research findings and thorough data analysis conducted on the infusion fluid monitoring system, it is deduced that the average precision for quantifying the infusion drop count per apparatus is recorded at 0.97 and 0.98 respectively, accompanied by a relative comprehension error of approximately 3%. Moreover, the accuracy in gauging the infusion fluid percentage for each apparatus is established at 7% and 9%, maintaining a relative precision level of 93% and 91% correspondingly. The infusion fluid monitoring, facilitated by the Wireless Sensor Network (WSN) technology integrating load cell and optocoupler sensors, emerges as a pivotal solution in augmenting control and surveillance throughout the infusion procedure. This advanced system not only demonstrates efficiency in quantifying the remaining infusion fluid percentage and the infusion drop count per minute but also facilitates seamless data accessibility via smartphones. Consequently, healthcare practitioners are empowered to simultaneously monitor multiple patients, thereby elevating the quality of healthcare services and fostering enhanced patient care. These substantive findings underscore the system's credibility in executing precise monitoring tasks.

Acknowledgments

In this moment, we extend our utmost gratitude to those who have contributed to the execution of this research. Firstly, we express our sincere appreciation to Mr. Yulkifli, our thesis advisor, for his invaluable guidance and mentorship throughout the research process. We also extend our thanks to Ms. Aulia Asman for her support and assistance in facilitating the publication of Intellectual Property Rights (IPR) for this research, as well as for providing the necessary funding. Additionally, we are grateful to Professor Yohandri for his insightful feedback and advice, which have greatly contributed to the improvement and refinement of this research. We highly value all the contributions and support provided, and we truly appreciate the fruitful collaboration.

References

[1] A. Sujiwa and R. R. Dianto, "Infusion Monitoring System For Patients Based On The Internet Of Things (IoT) With Android Notification System," *BEST : Journal of Applied Electrical, Science, & Technology*, vol. 4, no. 2, pp. 41–46, 2022, doi: 10.36456/best.vol4.no2.6172.

[2] W. Sardjono, A. Retnowardhani, R. Emil Kaburuan, and A. Rahmasari, "Artificial intelligence and big data analysis implementation in electronic medical records," in *Proceedings of the 2021 9th International Conference on Information Technology: IoT and Smart City*, 2021, pp. 231–237.

[3] Y. Darvina, Yulkifli, and M. Iqbal, "Rancang Bangun Sistem Pengukuran Suhu Dan Kelembaban Udara Menggunakan Sensor SHT75 Berbasis Internet Of Things Dengan Display Smartphone," vol. 22, pp. 97–104, 2019.

[4] K. K, S. V. S, J. M, and K. J, "A Survey of Systems used in the Monitoring and Control of Intravenous Infusion," *International Journal of Engineering and Technology*, vol. 11, no. 1, pp. 114–119, 2019, doi: 10.21817/ijet/2019/v11i1/191101054.

[5] J. H. Diaz, "Hypothesis: angiotensin-converting enzyme inhibitors and angiotensin receptor blockers may increase the risk of severe COVID-19," *J Travel Med*, vol. 27, no. 3, p. taaa041, May 2020, doi: 10.1093/jtm/taaa041.

[6] L. Costlow, "Maintenance intravenous fluids in children: AAP provides recommendation," *Am Fam Physician*, vol. 100, no. 4, p. 251, 2019.

[7] R. Shofiah, D. Prihatini, and S. Viphindrartin, "Perencanaan Sumber Daya Manusia Kesehatan (SDMK) Puskesmas Di Kabupaten Jember," *BISMA*, vol. 13, no. 3, p. 181, Nov. 2019, doi: 10.19184/bisma.v13i3.11633.

[8] G. Priyandoko, "Rancang Bangun Sistem Portable Monitoring Infus Berbasis Internet of Things," *Jambura Journal of Electrical and Electronics Engineering*, vol. 3, no. 2, pp. 56–61, 2021.

[9] P. Abril-Jiménez *et al.*, "Evaluating IoT-Based Services to Support Patient Empowerment in Digital Home Hospitalization Services," *Sensors*, vol. 23, no. 3, p. 1744, Feb. 2023, doi: 10.3390/s23031744.

[10] J.-K. Lee, K.-C. Yoon, and K. G. Kim, "Design of a Remote Monitoring System Based on Optical Sensors to Prevent Medical Accidents during Fluid Treatment," *Applied Sciences*, vol. 11, no. 21, p. 10124, Oct. 2021, doi: 10.3390/app112110124.

[11] M. B. Mollah, Md. A. K. Azad, and A. Vasilakos, "Secure Data Sharing and Searching at the Edge of Cloud-Assisted Internet of Things," *IEEE Cloud Computing*, vol. 4, no. 1, pp. 34–42, Jan. 2017, doi: 10.1109/mcc.2017.9.

[12] S. Feng and L. Tan, "Simulation of sports and health big data system based on FPGA and Internet of Things," *Microprocess Microsyst*, p. 103416, Nov. 2020, doi: 10.1016/j.micpro.2020.103416.

[13] G. Manogaran *et al.*, "Machine Learning Assisted Information Management Scheme in Service Concentrated IoT," *IEEE Trans Industr Inform*, vol. 17, no. 4, pp. 2871–2879, Apr. 2021, doi: 10.1109/tii.2020.3012759.

[14] M. Ghahramani, M. Zhou, and G. Wang, "Urban Sensing Based on Mobile Phone Data: Approaches, Applications, and Challenges," *IEEE/CAA Journal of Automatica Sinica*, vol. 7, no. 3, pp. 627–637, May 2020, doi: 10.1109/jas.2020.1003120.

[15] F. Ghahramani and J. Wang, "Impact of Smartphones on Quality of Life: A Health Information Behavior Perspective," *Information Systems Frontiers*, vol. 22, no. 6, pp. 1275–1290, 2019, doi: 10.1007/s10796-019-09931-z.

[16] L. Li, R. Liang, and Y. Zhou, "Design and Implementation of Hospital Automatic Nursing Management Information System Based on Computer Information Technology," *Comput Math Methods Med*, vol. 2021, p. 1824300, Dec. 2021, doi: 10.1155/2021/1824300.