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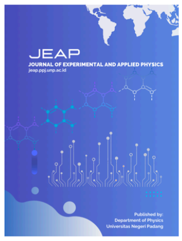

Monitoring Tool for Infusion Administration in Patients Using NodeMCU ESP32

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Abstract: The use of appropriate technology is essential in today's era, especially in the medical field, such as in the administration of IV fluids, where manual monitoring by medical personnel can lead to issues like depleted fluids or overdose if not properly supervised potentially resulting in suboptimal therapy, dehydration, or metabolic disorders due to changes in drip rate. Although previous research has developed automatic IV monitoring tools, they generally lack remote monitoring capabilities and tend to use microcontrollers inefficiently. From the problems that arise, a monitoring system for IV administration to hospital patients is designed using the NodeMCU ESP32. This tool starts from reading the number of IV fluid drops by the Photoelectric LM393 sensor, the data of which is then processed by the NodeMCU ESP32. The data is compared to a predetermined configuration, and if the number of drops exceeds a certain limit, a notification will be sent to the Blynk application. In addition, this tool also sends data on the number of drops to the Blynk application for remote monitoring. The results of the tool test show that the tool has a high level of accuracy with an average low error percentage of 5.55%, and is able to provide real-time data for monitoring and controlling the speed of infusion drops according to patient needs.

Keywords: Sensors, Photoelectric, NodeMCU, Monitoring, Infusion.

1. Introduction

Current technological advances and innovations continue to enhance human creativity in developing devices or systems that make tasks easier and more efficient. The use of appropriate technology is essential today, especially in the medical field [1], one example being the administration of infusion fluids. Infusion (intravenous therapy) involves delivering fluids containing drugs or nutrients into the bloodstream in precise and consistent doses according to patient needs. Improper infusion can negatively impact patients, thus requiring nurses to directly

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monitor both the infusion rate and the remaining fluid. This therapy is used for various conditions such as direct treatment, dehydration, or maintaining electrolyte balance [2]. The fluids are stored in sterile bags or bottles and flow through a tube into the bloodstream. The type and amount depend on the patient's condition and the purpose of treatment. Besides delivering fluids, IVs are also used for drug administration. Doctors recommend them during emergencies when medication needs to act quickly such as in dehydration, heart attack, stroke, or poisoning—where fast treatment is critical. However, time constraints, distance between patient rooms and control areas, and limited medical staff can delay care. If the IV fluid runs out and the nurse cannot immediately replace it, serious consequences may occur. Prolonged delays due to hospital limitations can significantly affect patient outcomes [3].

The infusion equipment currently used is still manual by medical personnel or nurses in installing and monitoring patients routinely. In the use of this infusion, it will cause problems if the use of the infusion is not monitored properly so that there will be a run out of infusion fluid or an excess dose of infusion which can endanger the patient [4]. Because of changes in the drip rate, fluids that are less or more than what is needed by the patient can cause suboptimal therapy, dehydration or metabolic disorders [5]. To overcome these problems, a tool and system are needed that are able to monitor and control how automatic infusion works remotely so that its use can be more effective and efficient. Previous research on a microcontroller-based infusion fluid replacement alarm system using a wireless infusion alarm system uses photodiodes and infrared as detectors for the presence or absence of drip infusion fluid, as well as to calculate the volume of infusion fluid, but this tool cannot be monitored remotely [6]. The Internet of Things-based infusion fluid drip monitoring system, this monitoring system uses infrared sensors, Arduino microcontroller modules, and data is sent via radio frequency. The test results show the maximum distance between the base-hotspot is 3.5 meters. This monitoring system will display data in the form of liquid droplets with ON and OFF status in real time with an average delay of 2 seconds. However, this tool uses 2 microcontrollers so it is a waste of costs [7].

The design and construction of a multi-device infusion monitoring and control system based on the Internet of Things (IoT) aims to automatically regulate infusion flow and control the delivery of medical fluids. However, a major drawback of this system is its reliance on two microcontrollers, which increases production costs [8]. Another system that uses message-based infusion fluid level monitoring employs a photodiode sensor to detect infusion levels and sends data via SMS. The limitation of this approach is that SMS restricts the amount of text that can be sent and requires MMS for transmitting media such as images, audio, or video [9]. A different system, which involves the design and development of an IoT-based infusion fluid monitoring tool using a smartphone application, utilizes an Arduino Uno microcontroller to control and transmit digital data. It uses an IR Obstacle sensor to detect infusion drips, displays the data on a 16x2 LCD, and sends it to the Thingspeak platform via an ESP8266 module. However, this system also requires two microcontrollers, leading to increased production costs [10]. Lastly, a system designed for automatic infusion monitoring based on Arduino is limited by the fact that its data output is only shown on an LCD screen and cannot be accessed via Android devices [11].

Based on the problems identified in previous studies, the author proposes the development of an infusion monitoring system using the NodeMCU ESP32, which offers several advantages over previous designs. Unlike earlier systems that utilized two microcontrollers leading to higher costs and increased complexity this tool uses only a single microcontroller (ESP32), making it more cost-effective and easier to implement. The system employs a Photoelectric LM393 sensor to detect the number of infusion drops in real-time, with data processed directly by the ESP32 and compared to a predefined threshold. If the number of drops exceeds the set limit, an automatic notification is sent to the Blynk application, and the drop count is also transmitted in real-time to the Blynk platform for remote monitoring via smartphone. Compared to earlier systems that only displayed data on an LCD or used SMS which is limited in character count and does not support multimedia this system utilizes IoT and real-time cloud-based monitoring, providing a more flexible and user-friendly interface. By simplifying hardware, enabling real-time alerts, and supporting remote access, this research offers a more practical, efficient, and affordable solution for medical personnel to monitor and control infusion therapy, directly addressing the shortcomings of previous systems.

2. Materials and Method

The system developed is an IoT-based infusion monitoring tool for hospital patients. This system is designed to make it easier for medical personnel to monitor and control the number of infusion fluid drops automatically and remotely. This tool consists of a Photoelectric lm 393 sensor to detect infusion drops, a Nodemcu ESP32 microcontroller to process data and internet connectivity, a servo motor SG90 to regulate the speed of the drops, and a blynk application as a user interface.

This research begins by designing an IoT-based infusion monitoring system using NodeMCU ESP32, LM393 Photoelectric sensor, and servo motor SG90. After the components are collected, programming is done using Arduino IDE to integrate the hardware with the Blynk application. The system is tested to ensure that the drip detection, alarm, and notification functions run according to design. Data is collected through simulation to evaluate the accuracy of the sensor and the system's response to infusion conditions. Analysis is carried out by comparing the results of automatic detection with manual observations to ensure the effectiveness of the tool. This method is designed to produce an efficient and accurate infusion monitoring solution.

This system works starting with the LM393 photoelectric sensor utilizing changes in light intensity to detect drips of infusion fluid. When a drop of fluid blocks the light path between the transmitter LED and the photodetector, a digital signal is generated through the LM393 comparator and forwarded to the Nodemcu ESP32 microcontroller for processing. This microcontroller functions as the brain of the system that processes data into information on the number of drops per minute (DPM). If the infusion fluid runs out or the number of drops stops, Nodemcu sends a notification via the Blynk application. A servo motor SG90 is used to regulate the speed of the infusion fluid drips based on commands from the Blynk application. The servo motor SG90 rotates the infusion tube clamp to increase or decrease the flow of fluid according to the patient's needs.

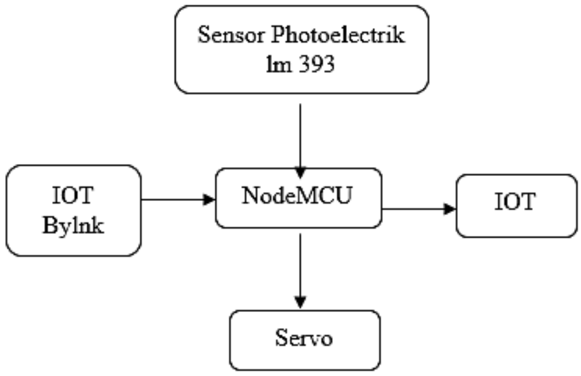

Figure 1. System block diagram

Figure 1 is an illustration of the Infusion Monitoring system consisting of an LM393 sensor used to detect each drop. NodeMCU ESP32 as a microcontroller that receives data from the LM393 to calculate the patient's infusion fluid drops per minute. The servo motor SG90 as a speed regulator of the infusion so that the infusion rate given to the patient is correct. The next design process is Figure 2 Flowchart of system programming algorithm.

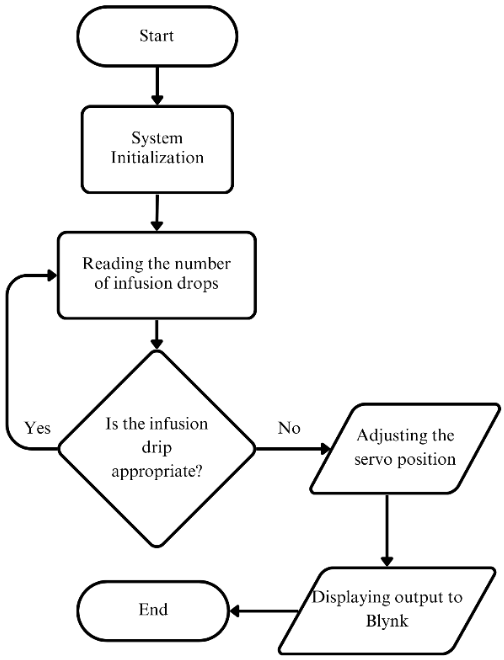

Figure 2. Flowchart of system programming algorithm

Figure 2 shows the flowchart of the microcontroller device design in the system. The design process begins with the use of Arduino IDE software to create a program that will be uploaded to the NodeMCU ESP32 board. The first step taken is the initialization of the pin system used for input and output operations. After the device is turned on, the system starts reading the number of infusion drops and also counting the drops per minute. Where if the infusion drops per minute are in accordance with the setpoint set in the blynk application, the servo will remain still. However, if the number of drops per minute does not match, the servo will adjust the drops per minute.

Then the data on drops per minute will be immediately sent to blynk via the internet network. The next design process is Figure 3 Electronic Circuit Design of the System Using KiCad 8.0 Software.

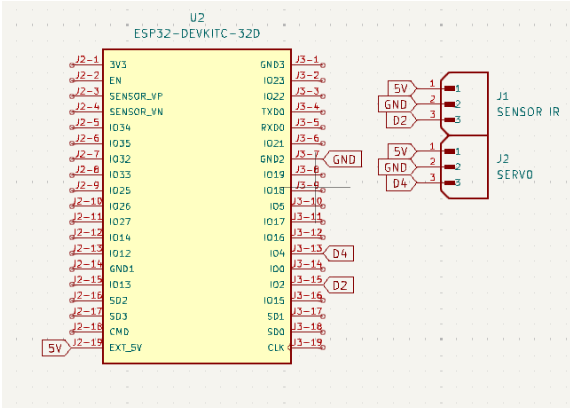

Figure 3. Electronic Circuit Design of the System Using KiCad 8.0 Software

Figure 3 displays the detailed system circuit, designed using KiCad 8.0, an open-source electronic design automation (EDA) software. In this circuit, the NodeMCU ESP32 is utilized as the central microcontroller to regulate and process data from the components. In the circuit, the NodeMCU ESP32 pin connection is built to incorporate the functionality needed in the infusion monitoring system. The LM393 is attached to pin D2 and serves as a drop detector. The LM393 sensor functions by transforming physical energy into electrical energy that the NodeMCU ESP32 can process. The LM393 will be attached and unplugged at its output voltage in tandem with the infrared that strikes it. The NodeMCU ESP32 digital pin then reads this voltage as a signal that corresponds to one infusion drop. The servo motor SG90 is connected to the D4 leg on the NodeMCU ESP32 which functions as a drip speed regulator. The speed of this infusion drip can be adjusted through the Blynk application. In this Blynk application, there are also results of the number of drops and drops per minute that flow to the patient. The next design process is Figure 4 illustrates the system design created in the Solidworks application.

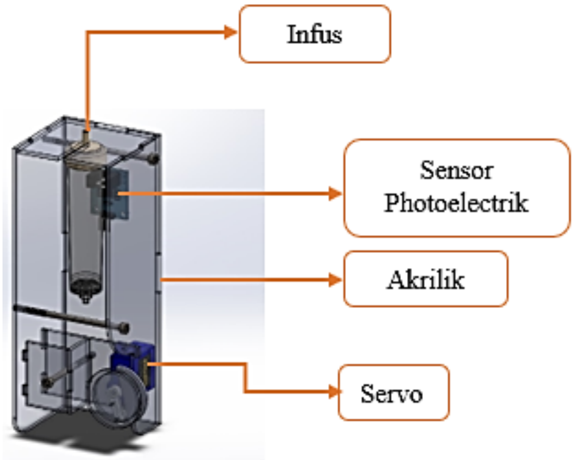

Figure 4. Illustration of System Design Created Using SolidWorks 2021

Figure 4 is an example of the system design to be implemented, created using SolidWorks 2021, a proprietary 3D CAD software that is not open source. In this design, the LM393 sensor is positioned on the infusion line to detect each drop. The SG90 servo motor is placed carefully so it can precisely control the drip speed of the infusion. The Blynk application is used to monitor the drip rate and can also control the servo motor, allowing the number of drops per minute to be adjusted according to patient needs.

3. Results and Discussion

The results of the study indicate that monitoring and controlling patient infusion is effective in maximizing patient supervision in hospitals. This system collaborates several main components including the NodeMCU ESP32 microcontroller, LM393 sensor, and servo motor SG90. NodeMCU ESP32 functions as the main component of the system that is responsible for processing input and output. NodeMCU ESP32 collects data from the LM393 sensor and processes it and sends the results of reading the LM393 sensor analog data to the Blynk application. The following are the results of the implementation of the patient infusion monitoring and control system hardware into a mechanical structure which can be seen in Figure 5 below.

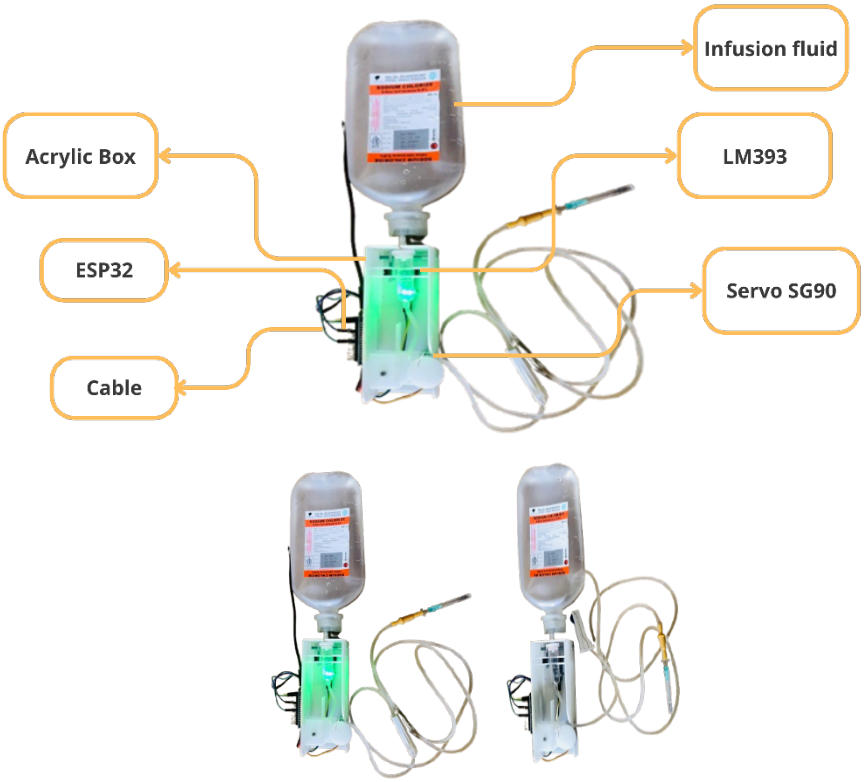

Figure 5. System Hardware

The hardware for the infusion monitoring and control system is implemented into a well-thought-out mechanical framework in Figure 5. All of the parts are arranged in this configuration to guarantee correct operation. In order to read the drops, the LM393 infrared sensor is positioned beneath the infusion where the liquid drips. The NodeMCU uses the information from the LM393 to determine and regulate the infusion drips' speed. A servo motor SG90 is used in this system to control the infusion drip's speed. The Blynk program allows for the monitoring and control of infusion drip data and infusion speed parameters. This set of elements not only guarantees effective patient care but also facilitates nurses' ability to manage several patients at once.

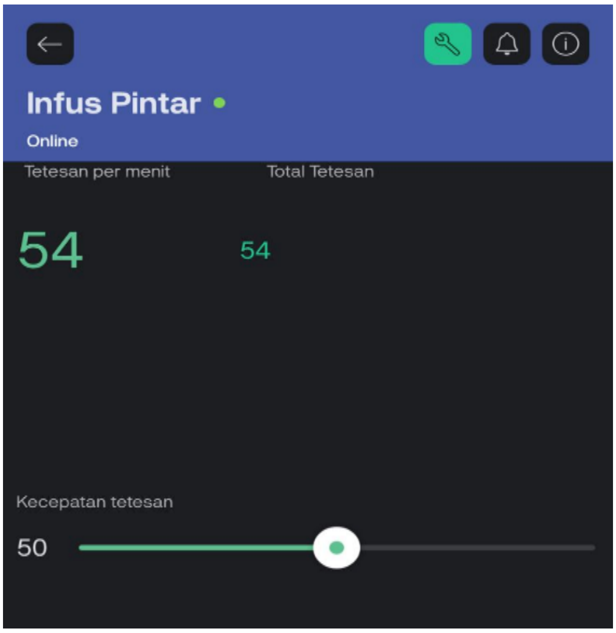

Figure 6. System Blynk display

The data obtained from this experiment allows for easier management of patient infusions in the hospital. After the data from the LM393 sensor was processed and the sensor data readings were displayed on the Blynk Application, the accuracy data collection experiment was conducted 10 times.

Table 1. Data on the accuracy of tool measurements made with standard tools

No	Total drops (manually counted)	Total drops (tools made)	Persentasi error
1.	9	9	0 %
2.	26	25	3.85%
3.	38	36	5.55 %
4.	54	54	0%
5.	69	69	0 %
6.	74	74	0 %
7.	103	102	0.98%
8.	125	129	3.2 %
9.	150	150	0%
10.	173	170	1.76%

In Table 1, the number of drops of infusion fluid calculated manually is compared with the results of the designed tool. The results show a high level of accuracy with an average error percentage of 1.53%. In several trials, the error percentage was 0%, indicating that the tool was able to read the number of drops with perfect accuracy. However, in several other trials there was a slight error. The next section presents the system accuracy measurement data through 10 trials. The measurement aims to determine how accurate the system is. Accuracy data is shown in Table 2 below.

Table 2. System accuracy data

Measurement of the	Number of Drops

1	56
2	56
3	55
4	55
5	55
6	55
7	55
8	54
9	54
10	54

In Table 2, the number of infusion fluid drops is measured when the servo motor SG90 is set to the 50% position. The results show high consistency, with most measurements yielding a drop count between 54 and 56. These small deviations are caused by fluctuations in the servo clamp mechanism. This data shows that the servo motor SG90 operates stably in regulating the speed of fluid droplets. The next section presents the test data of the device for adult and pediatric patients. This measurement aims to determine the percentage of servo angle for normal conditions of adult and pediatric patients. This measurement data is shown in Table 3 below.

Table 3. Test data for adult and pediatric patients

No	Adult DPM (49%)	Children's DPM (52%)
1.	59	33
2.	59	33
3.	59	33
4.	59	33
5.	59	33
6.	59	33
7.	60	33
8.	59	33
9.	59	33
10.	59	33

In Table 3, the number of drops per minute (DPM) is compared between the adult setting (49%) and the child setting (52%). The results show a noticeable difference, with the average DPM for adults recorded at 59, while for children it is 33. This demonstrates the system's ability to adjust infusion flow based on patient needs. The higher DPM in the adult setting reflects the generally greater fluid requirement for adults, who have larger body mass and blood volume compared to children. In contrast, the lower DPM in the child setting is suitable for pediatric patients to avoid fluid overload, which can be dangerous.

This infusion monitoring system is designed to maximize patient care by ensuring precise control and monitoring of infusion delivery. In the NodeMCU ESP32-based implementation, as shown by this data, the monitoring and control of the infusion operates by integrating the LM393 sensor to detect drops, and the servo motor SG90 to regulate the infusion speed. The combination of these systems ensures optimal performance of the monitoring and monitoring infusion system, both in monitoring patients and controlling the patient's infusion speed.

Research on the infusion monitoring and control system based on NodeMCU ESP32 has significant implications for the development of smarter and more efficient health technology. By utilizing this system, the process of monitoring infusions in patients can be carried out automatically and in real-time, reducing dependence on continuous manual supervision by medical staff. The system demonstrated an average accuracy of 98% in detecting infusion drops using the LM393 sensor, with a response time of less than 1 second when abnormal flow conditions occurred, such as blockage or nearing completion of the infusion bag. The integrated SG90 servo motor was able to effectively regulate fluid flow according to predefined patient categories (adult and child), maintaining consistent drip rates of ±59 drops per minute for adults and ±33 drops per minute for children across multiple trials. Notifications were successfully delivered via the Blynk application with minimal delay (approximately 2–3 seconds after event detection), showing the system's capacity for near real-time alerts. Compared to manual observation, which is prone to human error and delayed response—especially in high-patient-load environments—the automated system significantly enhances patient safety and ensures timely intervention. Additionally, the integration with IoT allows for seamless remote monitoring using smartphones, which was validated through consistent data transmission and stable cloud-based visualization during testing. These findings confirm that the developed system is not only technically feasible but also provides substantial operational benefits, making it a promising innovation for deployment in hospitals, clinics, and even home care settings to support responsive, technology-driven healthcare services.

Research on the NodeMCU ESP32-based infusion monitoring and control system has significant implications for the development of smarter and more efficient healthcare technology. By utilizing this system, the process of monitoring infusion in patients can be carried out automatically and in real-time without having to rely entirely on manual supervision by medical staff. This system is capable of detecting the number of infusion drops, adjusting the fluid flow rate, and providing notifications when the infusion is nearly empty or if there is a flow disruption. This enhances patient safety, reduces the risk of delayed treatment, and optimizes the time and workload of medical staff. Additionally, integration with IoT-based applications through the internet connection provided by NodeMCU ESP32 enables remote monitoring via smart devices, making this system relevant for use on various scales, from hospitals to home care. With the increased efficiency and accuracy demonstrated in this study, the use of an automatic infusion monitoring and control system can become an innovative solution in supporting responsive and technology-based healthcare services. Although this research demonstrates the effectiveness of the infusion control and monitoring system, there are still several aspects that require further investigation. One of them is the development of a more adaptive algorithm to improve the accuracy of infusion control by considering additional variables such as weight and type of infusion fluid.

4. Conclusion

The IoT-based infusion monitoring system using NodeMCU ESP32 has been successfully designed and tested. This system is capable of accurately detecting the number of infusion fluid drops using the LM393 Photoelectric sensor, processing the data through a microcontroller, and sending real-time notifications to the Blynk application for remote monitoring. The use of a servo motor SG90 allows for the adjustment of the infusion drip rate according to the patient's needs, whether adult or child, with consistent results. Based on testing, the device shows a high level of accuracy with a low error rate of 1.53%, making it reliable to support the efficiency of medical staff. This system provides an effective solution for monitoring and controlling the automatic administration of infusion fluids, thereby enhancing patient safety and minimizing the risk of errors in intravenous therapy. Optimization of sensor calibration and servo control can still be performed to improve the device's performance in the future.

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