Design And Implementation of Smart Infusion Pump For Telemedicine

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Abstract. This work focuses on the research and creation of smart syringe pumps for use in telemedicine applications. Delivery of fluids into the patient's body, including medications and nutrients, in a controlled environment is an important prerequisite for treatment that requires precise flow control. Telemonitoring and telemedicine are facilitated by the Internet of Things (IoT) and developments in wireless technology, which enable remote operation of medical devices. In this research, infusion monitoring can be carried out automatically with load cell sensors, optocoupler, Arduino Uno, and IoT technology, which uses the MQTT communication protocol to communicate data in real time. The resulting device can update sensor parameters dynamically and in real-time, allowing users to access them with precision and speed.

Keywords: telemedicine, Arduino Uno, Internet of Things

1 Introduction

Medical equipment that helps with the infusion procedure for a specific duration of time is called an infusion pump. The infusion innovation in question was initially unveiled by Dean Kamen and was given the name AutoSyringe [1]. However, infusion pumps are still underutilized; in some institutions, they are confined to specialized rooms due to their high cost and the fact that information is only displayed on the monitor screen of the device. A cost-effective instrument that performs the same function as an infusion pump while also being visible from a distance is therefore required [2]. Hence, there is a requirement for pioneering advancements in monitoring systems based on the Internet of Things (IoT). The patient's needs determine the need for an infusion fluid drop monitoring and control system, which can be operated by electronic devices [3][4][5].

The Internet of Things (IoT) refers to the paradigm wherein tangible devices communicate and share data via a communications network. MQTT is a primary distribution technology that utilizes lightweight publish/subscribe distribution [6]. This protocol is frequently used in communication networks. Implementing Internet of Things (IoT) technology in intravenous monitoring has the potential to enhance the effectiveness and security of patient treatment. Additionally, it can mitigate issues arising from

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delays in altering intravenous (IV) treatments for patients [7][8]. The objective is for this automated system to furnish up-to-the-minute data, enabling the medical staff to promptly implement essential measures to safeguard patients' well-being and security.

In the paper [7] the created Intravenous Infusion System determines the fluid level and drip rate, which are continuously monitored and shown on the dashboard and the nurse/officer's cellphone. The monitoring system and the nurse or attendant are also notified via warning signal if the drug level reaches the predetermined threshold and the decline rate alters.

The paper's subject is developing a low-cost [9], clever syringe pump for telemedicine that a physician can remotely monitor and control via the Internet. The syringe pump is positioned near the patient's bed. Telemonitoring and cellular network integration of telemedicine health services are functions of the Internet of Things (IoT) NODEMCU V3. An Arduino UNO is used by this device to manage the entire processing device.

This research will design and develop an Internet of Things-based intelligent infusion device that remotely regulates the flow rate per minute of infusion fluids in patients and monitors the condition of the infusion fluids. The implementation of this intelligent infusion system is anticipated to deliver valuable and timely data regarding the infusion status of every patient—without requiring manual intervention.

2 Research Method

The research development process consists of two stages: software and hardware. The hardware configuration comprises an Arduino serving as the controller and processing parameter data, followed by the ESP32 implementing the WIFI functionality on this tool. The volume of the infusion fluid in the container is computed using the data acquired from the Loadcell sensor in the form of a weight calculator. The number of infusion droplets in minutes is determined by the Optocoupler sensor, which is processed by Arduino Uno and transmitted by ESP32 to the Adafruit OI cloud server. After obtaining the data, it will be sent to the Arduino Uno microcontroller for further processing, transmitting serial data to the ESP32 NodeMCU. Through MQTT communication, NodeMCU EPS32 will transfer data to the cloud (Adafruit OI). Figure 1 generally displays the block diagram.

Arduino detects the servo motor's ability to control the infusion drops simultaneously and clamps the infusion hose to enable the necessary infusion fluid drop regulation. The NodeMCU ESP32 will transmit obsolete data when the two sensors identify the absence of infusion fluid. Subsequently, the medical team will be notified via the web or application regarding the infusion status. The Arduino IDE is the software used to transmit code to the microcontroller.

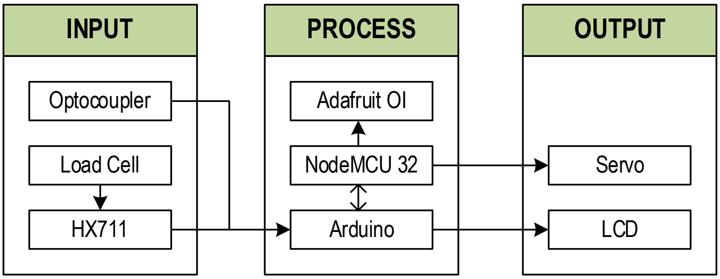
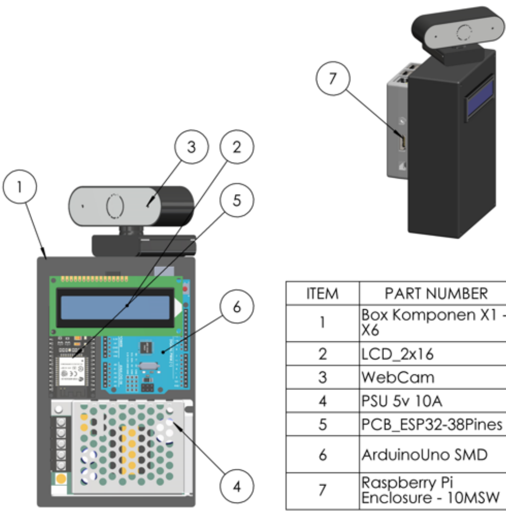


Fig. 1. The block diagram.

Figure 2 depicts the design of the Arduino Uno as the controller while monitoring the infusion. The NodeMCU ESP32 module establishes a connection to the internet for server-side monitoring. Placing the most recent value of data from the Arduino constitutes the channel. Furthermore, the particles discharged are regulated by a Servo Motor. If the infusion fluid requires immediate replacement, the Raspberry PI will autonomously transmit an image depicting the infusion's state. The hardware output will then be presented on the LCD as weight in millilitres, TPM, and anticipated time out. The webcam shall promptly record and store images of the infusion conditions; subsequently, the Raspberry Pi shall process and transmit the captured images to the smart infusion application and the internet.



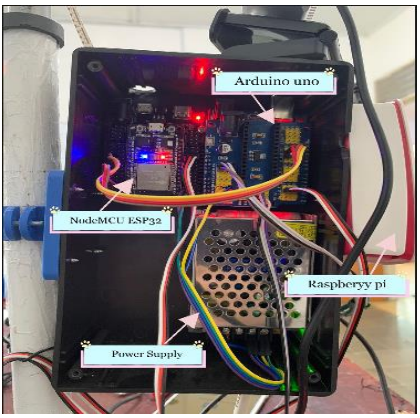
ITEM	PART NUMBER	QTY.
1	Box Komponen X1 - X6	1
2	LCD_2x16	1
3	WebCam	1
4	PSU 5v 10A	1
5	PCB_ESP32-38Pines	1
6	ArduinoUno SMD	1
7	Raspberry Pi Enclosure - 10MSW	1

Fig. 2. The design monitoring infusion

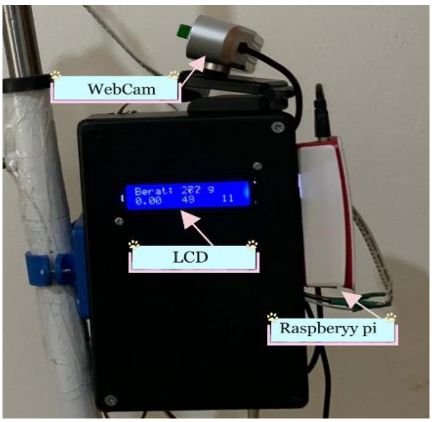
The research presented here aims to demonstrate the monitoring functionalities of the Android application. The Smart Infusion display is equipped with multiple capabilities, including (i) An infusion status feature that provides information on the percentage of infusion fluid and whether the infusion is complete, depending on the fluid's state. (ii) The feature will present the patient's name and birthdate, informing the user of the patient's age and identity and the kind of infusion the user has been using. (iii) The functionality will indicate the chamber in which the patient is situated, facilitating remote monitoring by nurses. (iv) the interface for the control function through which the nurse executes the remote control procedure. This display includes the patient's name and age, constituting the patient's identity, so nurses can more easily locate the patient through the Android application. (v) functionality about the time and quantity of infusion fluid drops, enabling the nurse to instruct the device to adjust the quantity and timing of infusion fluid drops according to the patient's requirements. This control display also includes a function for patient position information, which assists nurses in understanding the patient's condition.

3 Result and Discussion

This project's objective is to develop a remotely monitorable smart infusion. In its prototype form, the proposed device functions exceptionally well. The design of Internet of Things-based smart infusion hardware, featuring a Loadcell sensor that serves as a weight calculator for the infusion fluid volume in the infusion bottle, is depicted in Figure 3. (a) The number of droplets per minute (TPM) is determined using optocoupler sensors. The servo motor can simultaneously open or close the drip line on the infusion tubing. After being processed on an Arduino Uno, all collected data will be transferred via NodeMCU ESP32 to a cloud server. (b) The webcam simultaneously captures images of the patient's condition, which are processed and transmitted to the web and the smart infusion application via the Raspberry Pi.



(a)



(b)

Fig. 3. Sensor component placement on the smart infusion

As shown in Figure 4, the loadcell sensor is positioned in the suspended portion of the infusion at the uppermost position to obtain the weight. The infusion bottle also includes an optocoupler sensor for reading the drops and a servo motor for controlling the infusion drops. The component box, which is situated in the centre of the infusion pole, contains an LCD for displaying tool-related information. The Raspberry Pi is located next to a package that takes pictures of the infusion's state, and on top of the box is a WebCam.

(a) (b)

Fig. 4. The infusion monitoring system measures drips

3.1 Testing of Infusion Volume

This experiment involves determining the difference in weight between conventional measurements and those performed with a custom-made instrument by selecting the gross weight of the infusion container. Table 4.1 presents the results of the measurements.

Table 1. The measurements

Volume (ml)	Detection (ml)	Difference (ml)
500	550	50

The obtained weight difference was 50 millilitres, as indicated by the measurement results. The weight calculation of the optocoupler sensor and servo motor beneath the infusion container is pending, as indicated by the tool's measurements. The obtained data is utilized to configure the Arduino IDE to ensure the weight measurements on the device are consistent with those of traditional scales.

The results of measurements taken with conventional scales and the instrument scales that were designed were then compared in an experiment. Weight reductions of 50 ml each accurately evaluate the infusion bottle's mass. The testing involves reducing the volume of the infusion container from 500 ml to 50 ml. After the test, it was determined that four of the ten tests had weights ranging from 1 to 5 ml. This results from inadequate instrument calibration during the measurement process, which leads to erroneous weight addition.

3.2 Testing Infusion Fluid Drops using Optocoupler

Testing infusion volume with TPM measures how much flows per minute. This is mathematically or experimentally verifiable, as the packaging of each infusion set specifies that 20 droplets are equivalent to 1 ml (20 drops = 1 ml). The purpose of this test is to see if the amount of infusion fluid that is expelled matches the data on the packaging of the infusion set. This experiment was repeated fifteen times, utilizing both manual and system calculations. During each iteration, the rate of infusion fluid droplets per minute was measured for one minute. The stopwatch was employed to compare the values displayed in the Arduino IDE software to ensure that the results matched. The volume of infusion fluid drippings can be measured using a measuring cup designed to collect indicated fluids. Table 2 indicates three differences between the instruments and manual TPM calculations after 15 tests. This results from variations in the initial computation times.

Table 2. The test results for measuring the amount of infusion fluid droplets

Volume (ml)	TPM ((drop/minute)		Accuracy (%)
	Manual Readings	Instruments	
1	20	20	100
4,9	75	78	96
4	80	80	100
4,5	90	90	100
2	40	40	100
3	60	60	100
5	100	103	97
6,5	130	130	100
7,5	150	150	100
8	160	160	100
5	100	100	100
6	120	120	100

7	140	140	100
7,5	150	150	100
4,5	88	90	98

The smart infusion system has performed as expected overall because of tests that started with hardware design and continued with software development and hardware and software device combination. The optocoupler sensor detects infusion fluid drips when the load cell sensor detects the presence of a heavy load on the infusion bottle hanging on the sensor. At the same time, the servo motor may be configured to close or open the drip channel on the infusion hose. The Arduino will process all acquired data before transmitting it to the NodeMCU ESP32 serial monitor for network communication via the MQTT protocol; the Adafruit cloud, Web, and Smart Infusion applications will be displayed at this juncture. Simultaneously, the webcam takes pictures of the patient's state, which the Raspberry Pi processes and sends to the smart infusion program and the internet.

The smart infusion system has fulfilled four criteria during the system testing phase: weight reading, droplets per minute, condition estimation, and time estimation. Because this device is linked to the Internet of Things, medical staff can monitor and manage fluids more efficiently in real-time.

The results of ten trials differed by approximately 1–5 ml in the Infusion Volume test. Inaccurate weight increase is the result of improper calibration during measurement. The optocoupler sensor did in the Infusion Liquid Droplet test about 80% of the time, which means it works correctly. An average error rate of merely 0.4211% demonstrates the servo motor's excellent performance. The system remains within acceptable parameters despite the delivery delay in testing.

4 Conclusion

The smart infusion system performed successfully with this research, software development, and hardware-software device combination tests. The smart infusion system successfully fulfilled all four criteria established during the system testing phase. These criteria are as follows: weight reading, droplets per minute, condition estimation, and time estimation. This Internet of Things-connected device helps medical professionals monitor and control fluids in real-time.

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