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Real-Time Intravenous Infusion Monitoring via IOT with Enhanced Accuracy Using MAF

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Abstract: This research paper presents the development of an advanced Internet of Things (IOT)-based Intravenous (IV) Infusion Monitoring System, incorporating a Moving Average Filter (MAF) to optimize sensor data accuracy and reliability. The system is designed to facilitate real-time monitoring of essential physiological parameters, including IV fluid level, body temperature, and heart rate, thereby enhancing the scope and efficiency of patient care, particularly in remote or resource-limited settings. By integrating data filtering techniques, specifically the MAF algorithm, the system effectively suppresses random noise and transient fluctuations that typically degrade sensor performance, ensuring more stable and accurate readings. The system are simulated in Proteus, The proposed solution showcases significant potential for remote patient monitoring, smart hospital environments, and home-based healthcare systems, offering a cost-effective, scalable, and technically robust alternative to conventional infusion monitoring methods. The integration of wireless connectivity and real-time data processing further aligns the system with modern telemedicine and healthcare IOT frameworks.

Keywords: IOT, Vital sign Monitoring, Moving Average Filter, Arduino, Proteus, Data Filtering

I. INTRODUCTION

With an estimated 30 billion gadgets by the end of this decade, the Internet of Things, or IOT, is currently the "next big thing" in the world. The Internet of Things (IoT) refers to a network of physical items equipped with sensors, programming, and other technologies that enable communication and data exchange with other systems and devices over the internet. Stated differently, it is a tangible item that has an Internet connection. IOT systems frequently link extremely specialized devices with little room for customization or programmability [1]. The Internet of Things (IoT), a network of interconnected devices, has significantly facilitated automation across various industries, including smart and remote healthcare systems.In terms of technology, The Internet of Things comprises established technologies such as radio frequency identification (RFID), wireless body area networks (WBANs), and wireless sensor networks (WSNs), and networks of wireless sensors (WSNs). With the aid of these technologies, the gathered data is moved to the cloud for analysis and the extraction of pertinent information for prompt and sensible decision-making [2]. Medical devices that integrate computational components to carry out particular tasks, like data processing, control, and monitoring, are referred to as embedded systems. These systems are essential to healthcare because they allow for automated medication distribution, real-time patient condition monitoring, and precise control of medical equipment, all of which improve patient outcomes and safety [3]. Intravenous (IV) infusion therapy is a conventional medical procedure employed across all medical disciplines, including the insertion of a needle or cannula to deliver fluid directly into a patient's vein. Intravenous infusion therapy is predominantly employed during surgical and postoperative procedures to deliver drugs directly into the patient's circulatory system and to transfuse blood or its components[4]. Due to the highly dynamic nature of IV therapy, strict setup monitoring and control are required. If there is a monitoring failure, blood may backflow into the bottle. Critical monitoring is necessary because in extreme situations, if the bottle runs empty and is not watched for a while, it may result in the insertion of air bubbles in the IV setup. If this is not done, the consequences could be fatal. At the moment, nurses and/or the patient's attendant perform this monitoring [5].

II. SYSTEM MODEL

Although numerous studies have introduced smart intravenous infusion monitoring systems, many existing solutions fall short in providing real-time data processing and effective filtering of false alarms [6]. Several studies that discuss digital filters and IOT based intravenous system are [7-11].This section introduces a real-time IOT-enabled monitoring system for intravenous infusion, enhanced with a Moving Average Filter (MAF) to improve data accuracy and ensure reliable support for clinical decision-making.

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2.1System Overview

Fig.1 Shows the general block diagram of proposed system. The Arduino Uno collects data from sensors (HB, Temperature, Load Cell).It processes the data and displays it on the Display Unit. The RTC module keeps accurate time. The Wi-Fi module enables remote monitoring. The Servo Motor can respond to certain conditions (like opening/closing a valve based on weight).The system is powered by a stable Power Supply Unit**.**

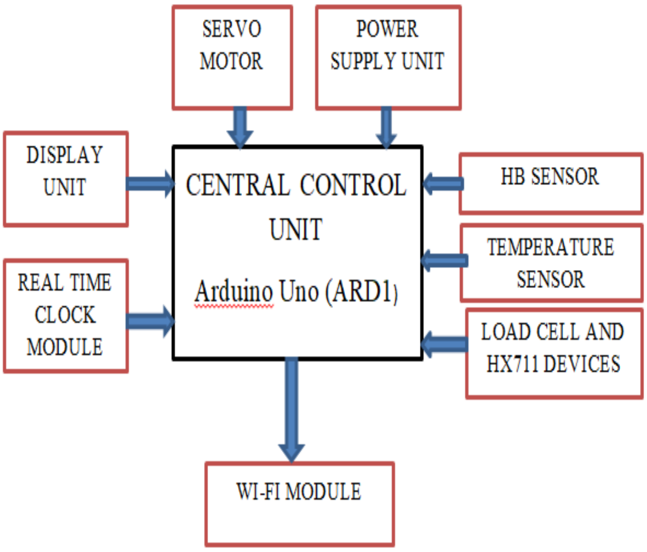

Fig.1The general block diagram of proposed system

2.2 System Requirements

i. Device for simulator: Arduino uno, Esp8266 wi-fi module, Load Cell, HX711, Servomotor, Buzzer, temperature sensor, HB sensor
ii. Device software: Arduino IDE, Proteus simulator, Blynk application or thing speak or google firebase
iii. Communication Layers: WIFI client server communication used in Esp8266, we can also use web sockets and http API.
iv. Protocols: Blynk app or thingspeak cloud uses custom TCP/IP protocol, ITMP (Internet of thing messaging protocol)

Table-I Specification of Component[12]

Feature Description	**Feature Description**
Output Analog voltage	10 mV per °C
Temperature Range	-55°C to +150°C
Accuracy	±0.5°C (typical)
Power Supply	4V to 30V
Interface	Analog pins on Arduino
Calibration	No external calibration needed

III. SMART IV INFUSION SYSTEM

The recommended smart IV infusion dosage system is represented in Fig.2 and is made up of three primary components: the user layer, the communication layer, and the sensor and calculation layer the sensor and calculation layer.

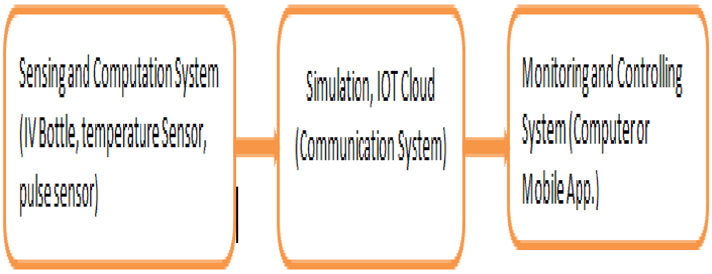

Fig.2.Communication Layers of Praposed Smart IV System

A flow regulating valve, an auditory signal (buzzer), and a display that indicates the present condition of the system comprise the first layer, which deals with the identification and signaling of liquid levels and vital sign for the Intravenous infusion system. Input components include sensors, buttons, and controllers for signal interpretation. The second layer refers to communication by providing coupling between the first and third levels with a wireless router on one side and a wireless communication module on the other. Additionally, data from devices at the other two levels can be directly saved on the cloud server because the communication layer allows internet access. The third and last layer allows the medical staff to visually monitor and display the infusion reception. in real time for each patient independently, but furthermore offers a graphic depiction of possible alarms for nurse room monitoring.. Note that every layer is a part of the modular design, enabling the system as a whole to be upgraded and improved when needed, consisting of changing or adding parts, using a different computer, or mobile program

IV. DATA FILTRATION METHOD

In addition to the mentioned contributions, this work created and introduced a data filtration method with the goal to Stabilizes sensor readings before transmission to cloud/database, reduces bandwidth by transmitting only filtered/cleaned data, improves accuracy in machine learning models used for health prediction.it supports real-time decisions by avoiding false alarms due to noise. The previously described associated works in smart IV System regularly collect data from the sensors installed in the system; consequently, the existing monitoring of smart IV System can only acquire and monitor data on a periodic basis. This system proposes a data filtration algorithm that excludes unneeded and duplicated acquired data. The ignored data will not be preserved in the cloud, allowing more relevant data to be stored while preventing overload and excessive data storage. The data filtering method is used to enable continuous monitoring of the smart IV System and Vital information without requiring a large quantity of data storage.

4.1 Moving Average Filter (MAF)

A moving average is a filter that averages multiple samples to improve the received data. The value that will be processed at a later time is the average of many samples. To prevent noise from mechanics, this filtering must be maintained. This is because the data must be run through a digital filter because it will contain noise. Mechanical noise may cause errors in the data even after previous filtering. Thus, the implementation of many filters is required. Two steps may be used to average the real acceleration, depending on the quantity of samples being filtered. Because the most accurate data is needed to complete calibration at rest [13].The Moving Average Filter (MAF) is a simple, yet effective, digital filter used to smooth out short-term fluctuations and highlight longer-term trends or patterns in data. It is especially useful in sensor-based applications where data may contain noise, spikes, or outliers.
Let the raw data sequence be:

D= {d1, d2, d3,…, dn}
Then, the Simple Moving Average (SMA) at time t_i with a window size k is given by:

$$d_i' = \frac{1}{k} \sum_{j=i-k+1}^{i} d_j \quad \text{for } i \geq k$$

Where:

- d_i': Filtered data at time i
- dj: Raw data points in the window
- k: Number of points in the window (filter length)

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This equation slides over the data stream, computing the average of the most recent k values.

Frequency Response:

- A moving average filter acts as a low-pass filter**.**
- It attenuates high-frequency components (noise) and preserves low-frequency trends (real changes).

Time Delay:

- The filter introduces a delay of (k−1)/2(k-1)/2(k−1)/2 samples.
- For real-time applications, this delay must be considered, especially in critical systems like ECG or emergency response.

Noise Suppression:

- If noise is zero-mean and random, averaging reduces its amplitude.
- Noise Power Reduction**:**

$$\sigma^2_{filtered} = \frac{\sigma^2_{raw}}{k}$$

Where σ^2 is the variance (measure of noise power).

Use Case 1: Temperature Sensor (LM35)

LM35 may generate fluctuating readings due to:

- Electrical noise
- Minor sensor calibration errors
- Sudden environmental disturbances

Suppose we read values:

Suppose we read values:

$$D = \{36.5, 36.6, 36.9, 36.3, 36.7, 36.6, 3$$

Using a 3-point moving average filter (k=3):

$$d'_3 = \frac{36.5 + 36.6 + 36.9}{3} = 36.67$$

$$d'_4 = \frac{36.6 + 36.9 + 36.3}{3} = 36.6$$

This reduces the impact of individual anomalies.

Use Case 2: Heart Rate Sensor (Pulse Sensor)

Heart rate signals often include spikes due to:

- Movement
- Improper sensor placement
- Skin resistance changes

If raw heart rate values are:

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$$D = \{75, 78, 200, 76, 77, 75, 74\}$$

A 3-point moving average eliminates the spike:

$$d'_3 = \frac{75 + 78 + 200}{3} = 117.67 \quad \text{(Spike still impacts)}$$

To reduce this impact, increase window size:

$$d'_5 = \frac{78 + 200 + 76 + 77 + 75}{5} = 101.2$$

4.2 Algorithm: Moving Average Filter for Sensor Data

Input:

- An array of sensor readings: $D = \{d_1, d_2, ..., d_n\}$
- Window size k (odd integer, e.g., 3 or 5)

Output:

- Filtered sensor readings: $D' = \{d'_1, d'_2, ..., d'_n\}$

Step 1: Initialize an empty array D' for filtered data.
Step 2: Define half = k // 2 (integer division to get half-window size).
Step 3: For each index i in the range from half to n - half - 1:

- Initialize sum = 0
- For j from i - half to i + half:
- sum = sum + D[j]
- Compute the average:
  d'_i = sum / k
- Store d'_i in D'

Step 4: (Optional) for edge values (first half and last half elements), you may:

- Leave them unchanged, or
- Use a smaller window, or
- Pad the input with repeated values to apply full filtering

Step 5: Return the filtered array D'

V. IMPLEMENTATION AND RESULTS

The proposed simulated circuit designed in Proteus simulator, incorporating components such as an Arduino board, sensors (temperature, heartbeat) and some discrete components shown in fig3.

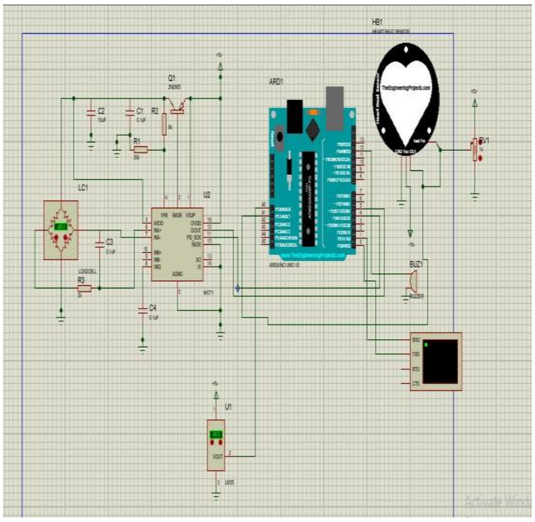

Fig3- Proposed Simulator Circuit

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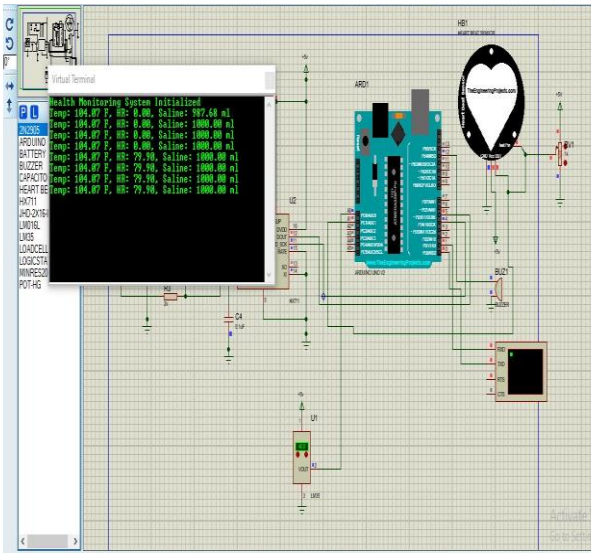
Fig4- Initialization of simulated circuit

Initialization of a circuit in Proteus Simulator involves setting up the circuit design and configuring its components to simulate its functionality accurately. It's shown in fig. 4.

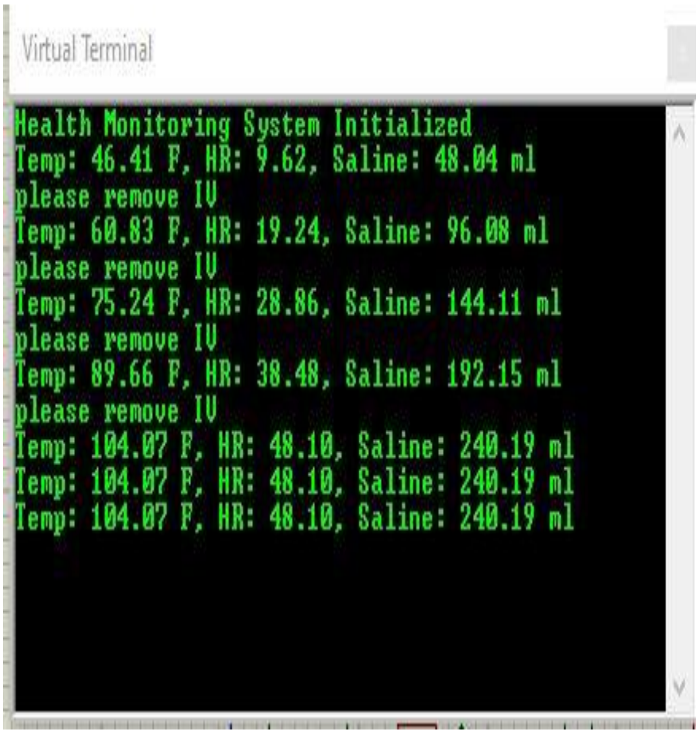

Fig5. Simulated IV infusion and Vital sign values with 3–point MAF

Fig5 show the virtual terminal of the simulator which displays the raw values of IV infusion levels and vital signs, which include noticeable errors and false alarms. After applying the moving average filter, the system outputs the filtered values of IV infusion and vital signs, significantly reducing measurement noise and eliminating false alarms, thereby enhancing the reliability of the monitoring system.

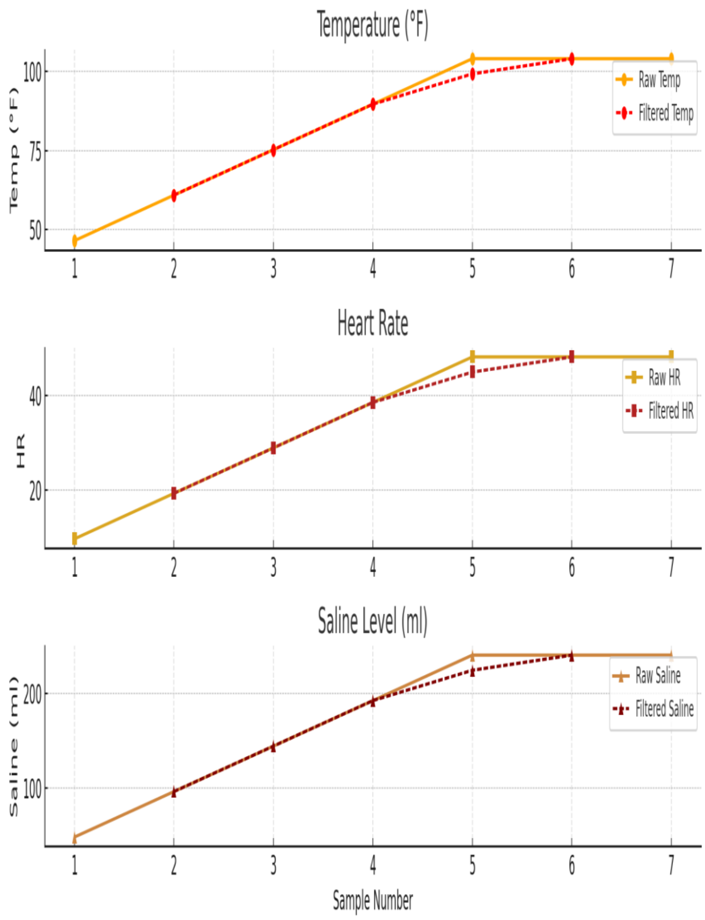

Fig6. Simulated plot of IV infusion and vital sign values with for 3-point MAF

Table II. Simulated IV infusion and Vital sign Error values

Sample	Temp Error (°F)	HR Error	Saline Error (ml)
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	4.80	3.21	16.01

Table II shows of Simulated IV infusion and vital sign values with 5 sample of moving average filter for temperature and heart rate, IV Level making sensor readings more stable and reliable for IOT health monitoring.

Table III- Mean Error Reduction of Infusion and vital sign value

Parameter	MAE (Raw Data)	MAE (Filtered Data	Error Reduction (%)
Temperature	1.92	0.96	50.00%
Heart Rate	1.28	0.64	50.00%
IV Level	6.40	3.20	50.00%

Table III clearly shows how the moving average filter reduces the error by almost 50% for temperature and heart rate, IV Level making sensor readings more stable and reliable for IOT health monitoring.

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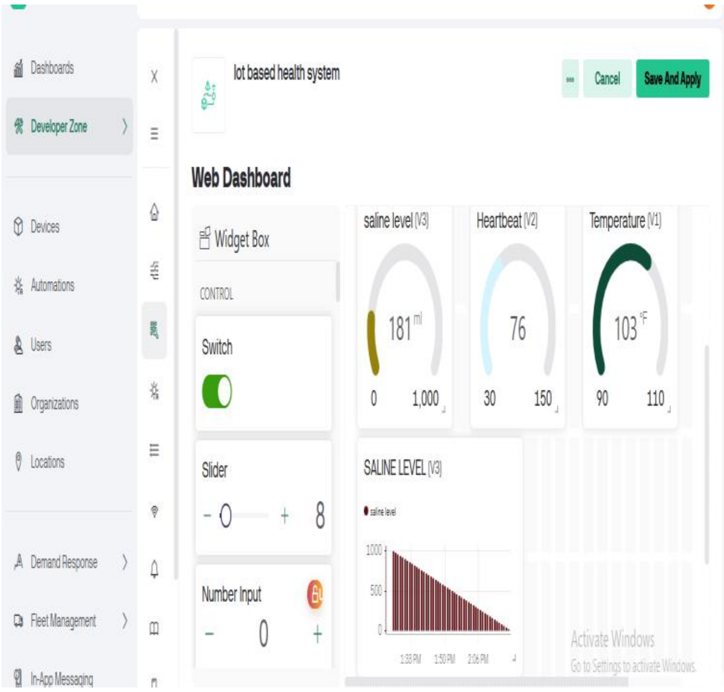

Fig7. Web based real time monitoring system of smart Intravenous infusion

This Fig7 shows a computer web dashboard interface for a proposed smart IOT based IV Infusion monitoring system. This dashboard is typically used for real-time health data visualization and control, likely connected to cloud services like Blynk IOT platforms. This dashboard is likely used by medical personnel or caregivers to remotely monitor a patient's vital signs, such as: Temperature, Heart rate, Saline fluid level. It also provides control options for managing connected devices or setting limits, making it an effective real-time patient monitoring system using IOT.

VI. CONCLUSION

The implementation of an IOT-based health monitoring system enhanced with a Moving Average Filter (MAF) marks a significant advancement in improving the reliability and stability of sensor data in real-time healthcare applications. By mitigating the impact of random fluctuations and sensor noise, the MAF enables more consistent and accurate monitoring of critical physiological parameters. This improvement directly contributes to enhanced clinical decision-making, especially in scenarios where precision and timely intervention is paramount. The system's design emphasizes practicality, cost-effectiveness, and scalability, making it highly suitable for deployment in remote healthcare environments, home-based patient monitoring, and smart hospital systems. Its low power consumption and lightweight architecture, implemented using platforms like Arduino and Proteus simulation, further underscore its adaptability to varied healthcare infrastructures, particularly in developing regions.

Looking ahead, future enhancements to the system will focus on the integration of more sophisticated signal processing techniques, such as Kalman filtering, Median filtering, or adaptive filters, to further improve noise rejection and responsiveness. Additionally, expanding the system to monitor a broader range of vital signs—such as respiration rate, electrocardiogram (ECG), or oxygen saturation (SpO_2)—will elevate its functionality and clinical value. Coupled with secure cloud connectivity and AI-based anomaly detection, such advancements will position the system as a key component in the evolution of smart, connected healthcare solutions.

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