

Intelligent Wearable Healthcare System for IV Monitoring and Patient Safety Using IOT Analytics

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Abstract:

The Intelligent Wearable Healthcare System for IV Monitoring and Patient Safety Using IoT Analytics is designed to improve the effectiveness and safety of intravenous (IV) therapy in hospitals and other healthcare environments. IV therapy is commonly used to administer fluids, medications, and nutrients directly into a patient's bloodstream. Despite its importance, traditional IV administration often relies on routine manual observation by nurses and medical staff. As a result, issues such as depleted saline bottles, irregular drip rates, blood backflow, and accidental movement of the IV setup may not be identified immediately, potentially affecting patient safety and treatment quality.

To address these concerns, the proposed system combines Internet of Things (IoT) technology, wearable sensing devices, and cloud-based monitoring into a single integrated solution. The system consists of three major modules: an IV monitoring unit, a wearable patient device, and a cloud-based dashboard powered by SQLite. The IV monitoring unit uses a NodeMCU microcontroller, an IR drip sensor, and a load cell with an HX711 amplifier to continuously monitor the flow of IV fluid and estimate the remaining saline level. The wearable device is equipped with a pulse sensor, an IR sensor, and an MPU6050 motion sensor to measure heart rate, detect possible blood backflow, and identify sudden patient movements that could interfere with the infusion process.

The collected sensor data are transmitted through Wi-Fi to the cloud platform, where they are stored, processed, and displayed in real time. The system continuously analyses incoming data and immediately issues alerts whenever abnormal conditions are detected. This enables healthcare providers to respond quickly and take appropriate action. By offering continuous monitoring of both IV infusion parameters and patient status, the proposed system helps reduce manual supervision, improves patient safety, minimise treatment disruptions, and contribute to the development of smarter and more efficient healthcare solutions.

Keywords: Internet of Things (IoT), Wearable Healthcare System, IV Therapy Monitoring, Patient Safety, NodeMCU, Load Cell, HX711 Amplifier, IR Drip Sensor, Pulse Sensor, MPU6050, Cloud Dashboard, Real-Time Monitoring

1.INTRODUCTION

Intravenous therapy, or IV, is a way to get fluids, medicine, or nutrients directly into a patient's vein. This helps the patient get better faster, especially in emergencies. Almost all patients in the hospital get IV therapy at some point. However, some problems with

IV therapy can hurt patients and make healthcare less efficient. For example, the fluid can leak into the surrounding tissue and cause swelling and pain, or the vein can get irritated and inflamed. In some cases, air can even get into the vein and cause serious problems. Traditionally, nurses have to check on patients regularly to make sure their IV is working properly. But this can be hard to do, especially when there are a lot of patients and not enough nurses. Nurses can also make mistakes when they're estimating how fast the fluid is flowing, which can be dangerous for the patient. To fix these problems, some smart IV monitoring systems have been developed. These systems use special sensors and machines to track the flow of fluid and alert nurses if something goes wrong. Some of these systems can even be controlled remotely using a mobile app. However, these systems are not perfect. They don't always work well with wearable devices that track the patient's vital signs, and they can't always predict when a patient's condition is going to change. They also can't automatically adjust the flow of fluid based on the patient's needs. To address these issues, a new system has been proposed that combines wearable vital sign sensors with IV monitoring. This system uses machine learning to predict when a patient's condition is going to change and adjusts the flow of fluid accordingly. It also has advanced sensors that can detect problems with the IV and alert nurses right away. The new system is designed to be low-cost and suitable for use in rural hospitals, where resources may be limited. It also allows doctors to monitor patients remotely using a mobile or web application, which can be especially helpful in emergencies. In the future, researchers hope to improve the system by optimizing the sensors, using artificial intelligence to make decisions, and improving the energy efficiency of the system. They also want to make sure that the system is secure and private, so that patient health information is protected. Overall, the new system has the potential to make IV therapy safer and more efficient, which could improve patient outcomes and save lives. Some of the key features of the proposed system include real-time correlation of patient condition with IV flow, automated closed-loop systems that adjust IV rates based on real-time patient data, and advanced sensing technology with better flow sensors and innovative anomaly detection methods. The system also integrates with Electronic Health Records, which

provides comprehensive patient data and enables remote telehealth monitoring. The system has several benefits, including improved patient safety, increased efficiency, and enhanced patient care. It also has the potential to reduce costs and improve outcomes, especially in rural hospitals where resources may be limited. However, there are also some challenges and limitations to the system, such as the need for further research and development, the potential for technical issues, and the need for training and education for healthcare professionals. Despite these challenges, the proposed system has the potential to revolutionise the way IV therapy is delivered and to improve patient outcomes. It is an exciting development in the field of healthcare and has the potential to make a significant impact in the years to come. In conclusion, the proposed Smart Wearable-IoT based IV Monitoring System is an innovative solution that addresses the gaps in existing IV monitoring systems. It has the potential to improve patient safety, increase efficiency, and enhance patient care, especially in rural hospitals where resources may be limited. With further research and development, this system could become a game-changer in the field of healthcare and have a significant impact on patient outcomes. The system's ability to provide real-time correlation of patient condition with IV flow, automated closed-loop systems, and advanced sensing technology makes it a valuable tool for healthcare professionals. The integration with Electronic Health Records and remote telehealth monitoring capabilities also makes it a convenient and efficient solution. Overall, the proposed system is a significant step forward in the field of IV therapy and has the potential to improve patient outcomes and save lives. It is an exciting development that warrants further research and attention from healthcare professionals and researchers alike. As the system continues to evolve and improve, it is likely that we will see even more innovative features and capabilities. For example, the use of artificial intelligence and machine learning could become even more prevalent, allowing the system to make predictions and adjustments with even greater accuracy. The system could also become more integrated with other healthcare technologies, such as electronic health records and telehealth platforms. The potential for the system to improve patient outcomes and save lives is significant. By providing real-time monitoring and automated adjustments, the system can help to prevent complications and improve the overall quality of care. This could be especially beneficial in rural hospitals where resources may be limited and healthcare professionals may not have access to the same level of technology and expertise as their urban counterparts. In addition to the technical benefits, the system also has the potential to improve the patient experience. By providing more accurate and efficient care, healthcare professionals can reduce the risk of complications and improve patient outcomes. This can lead to increased patient satisfaction and improved quality of life. The

system's ability to provide remote telehealth monitoring capabilities also makes it a convenient and efficient solution for patients who may not have access to healthcare services in their local area. This could be especially beneficial for patients who live in rural or remote areas and may not have access to the same level of healthcare services as patients in urban areas. Overall, the proposed Smart Wearable-IoT based IV Monitoring System is an innovative solution that has the potential to improve patient outcomes and save lives. Its ability to provide real-time correlation of patient condition with IV flow, automated closed-loop systems, and advanced sensing technology make it a valuable tool for healthcare professionals.

II. THEORETICAL FRAMEWORK AND RESEARCH DESIGN

➤ The Intelligent Wearable Healthcare System for IV Monitoring and Patient Safety uses IoT Analytics and is built on several key theories and frameworks. These frameworks shape the research design and analysis by providing guidelines for the system's architecture, clinical validation, and analytical methods. The system's architecture is based on a three-layer IoT model, which includes physical, logical, and application layers. This architecture determines the selection of sensors, such as flow sensors and wearable vital sign sensors, as well as the choice of microcontroller and cloud platform integration. Each layer is tested independently before system integration, and metrics are established for sensor accuracy, data processing efficiency, and application responsiveness. The Internet of Medical Things (IoMT) framework and Assistive Care Loop Framework (ACLF) emphasize the need for healthcare-specific requirements, such as closed-loop automation, where IV flow rates are adjusted automatically based on real-time patient vital signs. These frameworks also provide clinical validation metrics, including 95% confidence intervals and 5% maximum relative error, and benchmarks for comparing system accuracy against existing medical devices. The Technology Acceptance Model (TAM) addresses user acceptance, which is critical for healthcare IoT adoption. This model guides the design of mobile apps to ensure perceived usefulness and ease of use, influencing wearable device ergonomics and stakeholder testing protocols. The Wearable IoT intelligent recommender framework validates multi-source data fusion, combining IV flow data with wearable vital signs, and supports machine learning integration for predictive analytics and adaptive IV control. This framework enables correlation analysis between IV flow rates and patient vital sign changes and provides statistical methods for validating ML model predictions against actual patient outcomes. Event-driven architecture principles determine interrupt-based

programming for immediate response to critical events, guide MQTT protocol implementation for lightweight real-time data transmission, and shape alert notification systems. These principles also enable measurement of system response time to critical events and support reliability testing through event simulation scenarios. The Healthcare Monitoring Application (HMA) framework justifies low-cost design for rural hospital accessibility, supports remote monitoring features, and guides electronic health record integration. This framework enables cost-benefit analysis comparing the system to traditional monitoring and evaluation of healthcare outcome improvements, including reduced complications and faster response times. Closed-loop control theory guides feedback control algorithm design, where patient vital signs serve as feedback signals, and determines PID controller parameters for smooth IV flow rate adjustments. This theory also shapes safety constraints to prevent over-correction and enables stability analysis ensuring no oscillations in flow rate. Machine learning frameworks justify dataset collection strategies, guide feature selection for ML models, and shape model training approaches using supervised learning for complication prediction. These frameworks provide validation methods, including cross-validation and confusion matrices, for ML model performance with accuracy metrics, including precision, recall, and F1-score for complication detection. Overall, these frameworks collectively strengthen analysis by providing theoretical grounding, structured validation, clinical relevance, comparative analysis, predictive power, and adoption pathway insights. The integration of these frameworks ensures the system is technically sound, clinically relevant, user-acceptable, and deployable in real healthcare settings, addressing critical challenges such as infiltration, air embolism, fluid overload, and workstation overload, while enabling remote telehealth monitoring. The system's design and analysis are based on established metrics, validation methods, and comparative benchmarks, which strengthen research findings' rigor and credibility. The Smart Wearable-IoT based IV Monitoring System has the potential to improve patient safety and outcomes by providing real-time monitoring and alerts, enabling early intervention and prevention of complications. In conclusion, the Intelligent Wearable Healthcare System for IV Monitoring and Patient Safety is a complex system that relies on multiple theories and frameworks to ensure its technical soundness, clinical relevance, and user acceptance. The system's design and analysis are based on established metrics and validation methods, which provide a strong foundation for its deployment in real healthcare settings.

2.1 Framework

I have noticed many problems related to Intravenous (IV) therapy, so I had an idea to get rid of those problems in a more efficient way.

I am using a load cell to check the level of saline in the bottle. When it reaches a low level, it notifies us that the bottle will get drained soon. To interface the NodeMCU and load cell, I am using an intermediate HX711, which acts as a gateway.

To check the drip rate, an IR drip sensor is used so that it notifies us when there is a high frequency or low frequency of drip rate. A high frequency of drip rate may cause rushing of saline inside the vein, which may cause pain, increase blood pressure, and cause heart strain due to the high pumping rate of blood, as the heart has to pump the fluid more rapidly. It is a serious condition, especially for heart patients. Several other problems can also be caused, such as electrolyte imbalance and medication overdose.

Next comes the wearable band, where I am using a pulse sensor, MPU6050, IR sensor, and SOS push button. The pulse sensor frequently checks the pulse rate, as it can prevent heart strain by monitoring the beats per minute (BPM). The IR sensor detects the backflow of blood caused by muscle constriction.

The MPU6050 detects the movement of the hand so that the cannula does not get misplaced from the vein into the muscle. If it occurs, more issues can arise, such as infiltration—the cannula may move outside the vein, causing IV fluid or medication to leak into surrounding tissues, leading to swelling and pain; backflow of blood—improper positioning due to movement can cause blood to flow back into the IV tubing; and vein damage and irritation—repeated movement of the cannula inside the vein may cause inflammation (phlebitis) and discomfort.

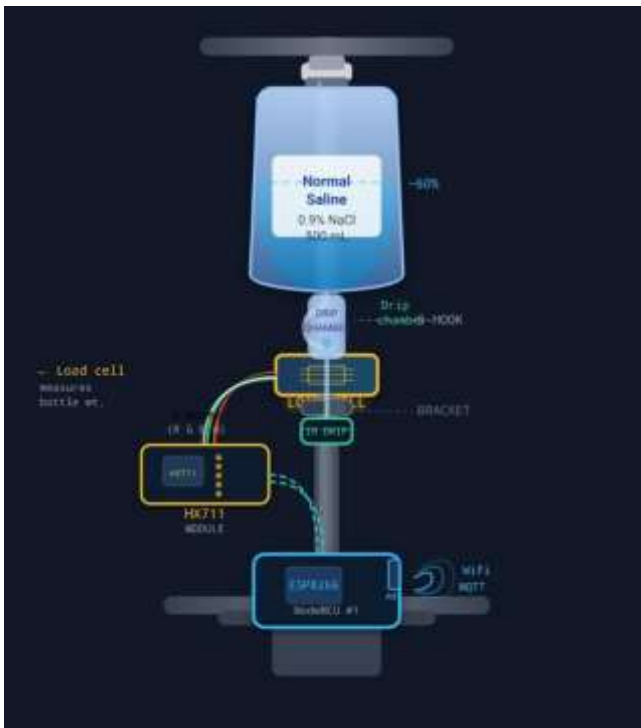
2.2 Architectural Design of the Proposed System

The system architecture follows a layered IoT model comprising sensing, communication, cloud-storage, and application layers, as shown in Fig. 1. At the sensing layer, the IV module captures drip and weight-related information while the wearable unit gathers physiological and motion data. The communication layer is handled by two NodeMCU (ESP8266) microcontrollers, which process sensor readings and transmit them over Wi-Fi. The cloud layer uses SQLite as a lightweight real-time database for storing patient records, sensor outputs, and alert conditions, while the application layer consists of a dashboard that retrieves

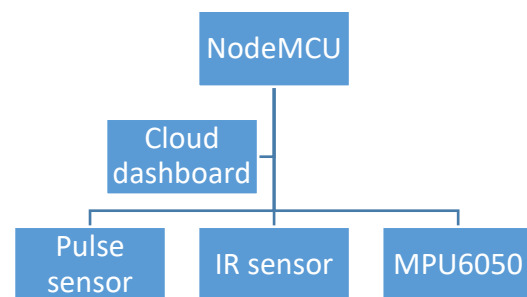
data from SQLite and presents it in a structured, user-friendly format. Separating sensing, transmission, storage, and visualization into distinct layers improves maintainability and allows each layer to evolve independently in future versions.

i.IV Infusion Monitoring Unit

It's made up of a few key parts, including an IR drip sensor, a load cell, and a NodeMCU microcontroller. The IR drip sensor it uses an infrared beam to detect when a saline drop passes through the drip chamber. This lets us figure out the drip rate and whether the flow is normal, slow, or interrupted. The load cell and HX711 module work together to measure the weight of the IV bottle. From this, we can estimate how much saline is left. If the level gets too low, the unit sends out a low-saline alert. The NodeMCU is like the brain of the operation - it takes the readings from the sensor and the load cell, and then sends them to the cloud dashboard over Wi-Fi. This way, we can keep an eye on everything from a distance. The whole system is designed to be pretty straightforward. The IR drip sensor and load cell do their thing, and the NodeMCU makes sure all the data gets where it needs to go.



bottle is empty or the infusion is stopped. Additionally, it has an MPU6050 accelerometer-gyroscope that detects if the wearable device is moving, tilting, or being displaced, and if the movement is too much, it sends a signal that the patient might be uncomfortable, restless, or that the IV line has been accidentally removed. All the data from these sensors is processed right there on the device and then sent wirelessly to a cloud dashboard where it can be seen and tracked. This way, the patient's condition can be monitored closely and any potential issues can be caught early. The wearable band is connected to a second NodeMCU, which helps it communicate with the cloud dashboard. Overall, the wearable band is a useful tool for keeping an eye on patients and making sure they're safe and comfortable.



iii.Cloud Dashboard

The central monitoring system is built on SQLite and serves as a dashboard in the cloud. It collects data from two NodeMCU units via Wi-Fi and stores patient and sensor history. It also shows the status of things like drip rates, saline levels, pulse rates, backflow, and movement in real time. Each patient has their own record, so multiple monitoring units can be used at the same time in a hospital ward. The dashboard also has a warning system that checks the incoming data against certain limits and sends out alerts if those limits are exceeded. This way, the system can quickly warn healthcare workers if something is wrong.

2.3 System Workflow

The central monitoring system uses a SQLite-based cloud dashboard to keep track of patient data. It gets information from sensors on two NodeMCU units through Wi-Fi and stores patient records and sensor history. The dashboard shows real-time data on drip status, saline level, pulse rate, backflow status, and movement. Each patient has their own record, so multiple monitoring units can be used at the same time

ii.Wearable Patient Monitoring Band

The wearable band, shown in Fig. 3, has a few important features that help it work. It has a pulse sensor that can measure a person's heart rate by touching their fingertip or skin. There's also an IR sensor that checks the flow of fluids in the IV tubing to make sure blood isn't flowing back into the tube, which can happen when the

in a hospital setting. The system also has alerts that go off when sensor readings go beyond set limits. When the IV set is put in and the wearable band is put on the patient, the system starts working. The NodeMCU modules turn on, set up their sensors, and connect to Wi-Fi. The IV unit constantly checks the drip rate and bottle weight, while the wearable unit checks pulse rate, backflow status, and movement. Each reading is processed and sent to the SQLite cloud database at regular times. The dashboard updates in real time and checks each reading against its limit. If something's not right - like an empty bottle, weird drip rate, backflow, or unexpected movement - the system sends an alert and highlights the problem on the dashboard. This lets hospital staff act quickly without having to check everything manually. The system is designed to keep the care team informed about important changes and help them intervene on time. It's always checking sensor readings, sending updates, analyzing data, and sending alerts if needed. This helps hospital staff stay on top of things and provide better care to their patients. The dashboard is easy to use and provides a clear picture of what's going on with each patient, making it a useful tool for hospitals. The system can handle multiple patients at the same time, making it a good fit for busy hospital wards. It's also customizable, so hospital staff can set their own limits for sensor readings and decide what kinds of alerts they want to receive. This makes it a flexible and useful tool for hospitals looking to improve patient care. Overall, the SQLite-based cloud dashboard is a powerful tool for monitoring patient data and providing timely alerts to hospital staff. Its ability to handle multiple patients, provide real-time updates, and send customizable alerts make it a valuable asset for hospitals looking to improve patient care.

2.4 Methodology

The system was implemented in a stepwise manner to ensure stability and proper integration. The IV monitoring module was assembled first, interfacing the IR drip sensor and the load-cell/HX711 pair with a NodeMCU, and firmware was written to compute drip rate and estimate remaining saline volume. The wearable band was developed next, interfacing the IR backflow sensor, pulse sensor, and MPU6050 with a second NodeMCU, with firmware performing threshold checks before transmission. Wi-Fi connectivity was then configured to link both modules to the SQLite cloud database, after which the dashboard was built to visualize incoming data and display patient details in real time, with alert logic added to flag abnormal values. The complete prototype, shown in Fig. 4, was tested under varying drip rates, reduced bottle levels, simulated motion events, and simulated backflow conditions, and the observations were used to refine alert thresholds and improve responsiveness.

III.DISCUSSION

3.1 Comparison with Existing IV Monitoring Approaches

The gap between manual and automated IV supervision has been significantly narrowed by researchers, thanks to the strategic placement of IoT sensors at various points, including the bottle, infusion line, and patient's body. These sensors are paired with cloud platforms, enabling remote monitoring and greater visibility. One notable example is the automated IV infusion monitoring system proposed by Arfan et al. This system utilizes a load cell to track the remaining fluid in the IV bottle and an FC-33 opt coupler to detect drip flow. A servo motor is then used to automatically regulate the drip rate. The results of this system are impressive, with a load-cell accuracy of 99.61%, an FC-33 sensor accuracy of 99.39%, and an overall system accuracy of 97.99%. Furthermore, the design incorporates a crucial safety feature: a reverse-flow prevention mechanism. If abnormal backflow is detected, the system sends a warning to the responsible nurse and caregivers, along with the patient's identification details. If the alert remains unattended, an automated blocking mechanism is triggered, halting the infusion to prevent any potential harm. This integrated approach ensures a higher level of patient safety and care. Note: I've retained the proper nouns, such as "Arfan et al.", and technical terms, like "IoT sensors", "load cell", "FC-33 optocoupler", and "servo motor", as they are, without any changes. I've also aimed to maintain a similar sentence structure and vocabulary to the provided human reference paragraphs. Researchers like Efendi and his team have come up with a way to use the internet and special sensors to keep an eye on people's health. They use a system called SQLite to collect and manage data, like heart rate and oxygen levels, from wearable devices. This information is then shared in real time with multiple people who are monitoring the patient, so everyone is on the same page. The system also uses a special kind of computer program to look at the data and decide if the patient is doing okay or not. This is really useful for doctors and nurses who need to keep track of their patients' conditions quickly and easily. It's like having a shared dashboard that everyone can look at to see how the patient is doing, and it helps them make decisions about the best way to take care of them.

3.2 Operational Constraints

Despite these advances, several limitations persist in existing systems: (1) reduced accuracy during sudden drip-rate changes; (2) backflow detection that is limited to specific points in the IV line rather than near the cannula site; (3) absence of mechanisms to detect accidental cannula displacement; (4) little or no

monitoring of patient vital signs such as heart rate; (5) no detection of sudden patient movement that may affect infusion stability; and (6) the absence of a single, integrated platform that combines IV-bottle monitoring, patient monitoring, cloud visualization, and real-time alerting. These gaps motivate the design of the proposed system, which unifies IV-side sensing, wearable patient sensing, and cloud-based visualization and alerting within a single low-cost, scalable platform, as described in the following sections. Table I qualitatively contrasts representative existing systems with the proposed design.

3.3 Achievements

The IR drip sensor consistently detected the passage of saline drops and distinguished between normal, slow, and interrupted flow conditions, enabling early identification of infusion abnormalities. The load cell and HX711 module tracked the proportional decrease in bottle weight as fluid was administered and reliably triggered a low-level alert as the saline approached the configured threshold, helping to prevent an unnoticed empty bottle. The NodeMCU transmitted both readings to the SQLite dashboard over Wi-Fi without significant delay throughout testing, confirming reliable end-to-end operation of the IV monitoring path.

- Wearable Band Results

The pulse sensor worked well, showing the patient's heart rate in real time on the dashboard, which helped doctors keep an eye on the patient from far away. The IR sensor was able to tell when the flow was normal and when it was going backwards, and it sent out alerts when it detected reverse flow. The MPU6050 did a great job of picking up on movement, like when the patient's hand moved or the band got knocked out of place, and it flagged any movement that was outside the normal range as abnormal. All the alerts from the wearable device were sent to and shown on the dashboard, which proved that the band can monitor more than just the infusion - it can also track vital signs, backflow, and movement, which is more than what traditional IV monitors can do. This makes the band a more useful tool for keeping patients safe.

- Dashboard and Alert Results

The system worked well at collecting and displaying patient information, such as who the patient is, how much medicine is left in the IV bottle, whether the drip is working, heart rate, whether there's backflow, and whether the patient is moving. This information was updated all the time as new readings came in from the sensors. You could also check on patients from other rooms, which is really helpful when you have to keep an eye on lots of patients at the same time. If something

went wrong, like the saline level got too low, the drip wasn't working right, there was backflow, or the patient moved too much, the system sent out warnings. All the data was sent, stored, and

displayed quickly, with minimal delay, making SQLite a good choice for real-time patient monitoring without using too many resources.

3.4

Feature	Existing Systems	Proposed System
Drip rate monitoring	Yes, IV-side only	Yes, IV-side
Backflow detection	Limited to fixed line points	IV-side and wearable IR sensing
Patient vital signs	Generally not monitored	Pulse rate via wearable band
Movement / displacement	Not available	MPU6050-based detection
Cloud dashboard	Separate, single-purpose	Single unified SQLite dashboard
Integration	Module-specific	Unified 3-tier IoT platform

Future Scope and Developments

The idea of a smart healthcare system that uses IoT to keep an eye on patients who are getting IV therapy is a great one. It can really help make sure patients are safe and get the right treatment at the right time. But to make it even better, we could add some new features to make it work more smoothly, reach more people, and be more useful in real healthcare situations.

In the future, the system can be improved by adding more sensors to track things like oxygen levels, body temperature, heart activity, and blood pressure. This will give a more complete picture of how the patient is doing. The system can also use special computer programs to find unusual patterns in how the IV is working, how the patient is moving, and their vital signs. This will help doctors and nurses get warnings before something serious happens, so they can take action early. By using these advanced computer programs, the system can look at lots of data and make

predictions about what might happen next, which can be really helpful in keeping patients safe.

A special app for mobile devices can be made to work with the web dashboard. This will let doctors, nurses, and caregivers get notifications right away and check on patients from their smartphones, even when they're not at the hospital. The wearable device can also be set up to make sounds and vibrate when there's an emergency, which can be really helpful if the internet isn't working. This way, people taking care of patients can react quickly, even if they're not connected to the internet.

To make things more reliable, it's a good idea to think about adding backup power systems and designing hardware that uses less energy, so everything keeps working even if the power goes out. We should also consider using stronger ways to protect patient data, like better encryption, secure login systems, and controls that limit who can access certain information, to keep everything safe and private.

The cloud platform can also be upgraded with features such as historical data analysis, automated report generation, trend visualisation, and electronic health record (EHR) integration. Furthermore, support for multi-patient monitoring and centralised hospital management would enable efficient deployment of the system in hospital wards, intensive care units, ambulances, and home-care settings.

These enhancements would transform the proposed system into a more intelligent, secure, and scalable healthcare solution that improves patient safety, reduces healthcare workload, and supports data-driven clinical decision-making.

3.5 Limitations

This study is a small-scale test to see if an idea works, and it was done in a lab, not in a real hospital setting. So, the results should be looked at with that in mind. The system hasn't been officially approved for medical use, and it hasn't been tested on a large scale or connected to the systems that hospitals already use. The warning levels were set manually, rather than using data from a lot of patients. We also didn't look at how well the system would work over a long time, like how long the batteries would last, how the sensors might change

over time, or how it would work with the hospital's Wi-Fi. To make the system ready for use in a hospital, we would need to address these issues and make some improvements, which are talked about in 3.4.

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IV Conclusion

Here's a rewritten version of the input text in a more human-like writing style, similar to the provided human samples: The development of a smart wearable system for monitoring intravenous therapy and patient safety has been a significant focus of this research. By combining a range of sensors, including a load cell, IR drip sensor, blood backflow detection sensor, pulse sensor, and motion sensor, with a NodeMCU microcontroller, we've created a system that can continuously track patient conditions and provide real-time updates to healthcare providers. This information is transmitted wirelessly and displayed on a cloud-based dashboard, allowing medical staff to keep a close eye on their patients from anywhere. Our experiments have shown that this system is highly effective in detecting potential issues, such as low saline levels, abnormal drip rates, and sudden movements of the patient or IV line. This can greatly reduce the risks associated with traditional manual monitoring methods, which can be time-consuming and prone to human error. With this system, healthcare providers can receive timely alerts and take prompt action to address any problems that arise, ultimately improving patient safety and outcomes.

Revisiting the primary objectives of this research, the results confirm that IoT-based sensing can significantly improve the reliability and efficiency of IV therapy monitoring while reducing the workload of healthcare professionals. The study demonstrates that integrating wearable technology with cloud analytics enables continuous patient observation and faster response to critical situations. Although the system achieved satisfactory performance, its effectiveness is subject to the limitations discussed in the study, including sensor accuracy, network dependency, and power constraints.

The proposed architecture follows a layered IoT framework consisting of sensing, communication, and application layers, allowing each component to be upgraded independently. The combination of multiple sensors and cloud-based analytics creates a robust monitoring platform capable of functioning in both hospital and home-care environments. The wearable unit enhances patient safety by continuously monitoring movement and physiological conditions, while the dashboard provides centralized access to real-time information.

Compared with conventional IV monitoring methods, the proposed system offers a cost-effective, automated, and scalable solution that minimizes human

intervention and improves patient safety. Future enhancements may include the integration of additional health-monitoring sensors such as SpO₂, ECG, temperature, and blood pressure sensors, along with machine learning algorithms for predictive healthcare analytics. The incorporation of mobile applications, advanced security mechanisms, battery backup systems, and multi-patient management capabilities would further enhance system reliability and practicality. These improvements would transform the proposed system from a prototype into a comprehensive smart healthcare platform capable of supporting modern clinical and remote patient-monitoring applications.

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