Chapter 13

Book Chapter

Multimodal sensor Integration for Advanced Patient Monitoring

Priyanka G N [*1], Hanamant R Jakaraddi [†2], and Ashoka S B [‡3]

[1]Department of MCA, Acharya Institute of Technology, Bangalore
[2]Department of MCA, Acharya Institute of Technology, Bangalore
[3]Department of Computer Science, Maharani Clustered University, Bangalore

Abstract

Advanced patient monitoring in healthcare is experiencing significant technological advancements through the integration of various sensors, including load cells for saline level monitoring, autonomous bed position adjustments, and the incorporation of the MAX30100 accelerometer for pulse rate monitoring, body movement, and temperature sensing. The primary aim is to enhance patient safety by facilitating real-time notifications for healthcare staff and enabling early hazard detection, such as infections, through advanced sensor data processing. Additionally, the implementation seeks to enhance patient comfort by integrating intricate patient monitoring features and auto bed positioning driven by sensor inputs. The Blynk smartphone app acts as a central interface for remote monitoring and control, providing real-time insights for healthcare professionals. This comprehensive approach leverages modern sensor technology to optimize patient outcomes, streamline healthcare processes, and enhance care delivery efficiency. The integration of these advanced sensor technologies, focusing on saline levels and automated bed control, signifies a substantial stride in improving patient outcomes and advancing healthcare delivery in modern healthcare settings.

*Email: priyankagnroyal64404@gmail.com Corresponding Author
†Email: hanamant2504@acharya.ac.in
‡Email: dr.ashoksbcs@gmail.com

Keywords: Patient Monitoring. Sensor Integration. Autonomous Bed Positioning. MAX30100 Accelerometer. Patient Safety. Remote Monitoring. Healthcare Technology.

1 Introduction

Pandemics place immense strain on healthcare systems, manifesting in several critical challenges. Patient overload during pandemics like COVID-19 overwhelmed hospitals, with intensive care units and emergency departments often filled to capacity, leading to shortages of beds and critical care resources. This surge outstripped the available medical supplies and equipment, causing widespread shortages of personal protective equipment (PPE), ventilators, and other essentials. The Spanish flu similarly saw hospitals lacking sufficient staff and medical supplies to cope with the massive influx of patients. Non-urgent medical procedures were postponed to free up resources, delaying treatments for other serious health conditions and worsening patient outcomes. Healthcare workers faced significantly increased workloads, long hours, and high patient-to-nurse ratios, leading to physical and mental exhaustion. The risk of infection was a significant concern, with many healthcare workers contracting the virus due to inadequate PPE and prolonged exposure to infected patients, seen in both COVID-19 and the Spanish flu. The psychological toll was profound, with increased instances of burnout, anxiety, depression, and PTSD among healthcare professionals.

Operationally, many healthcare facilities were not equipped to handle the sudden increase in patient numbers, necessitating the setup of temporary field hospitals in suboptimal conditions. The global nature of pandemics disrupted supply chains for medical supplies and medications, exacerbated by lockdowns and travel restrictions during COVID-19. Effective communication was also disrupted, with inconsistent messaging and lack of clear guidelines contributing to confusion and inefficiencies in response efforts. The overwhelming demand often led to compromised care quality, forcing healthcare providers to make difficult decisions about resource allocation, sometimes resulting in suboptimal treatment for patients. Mortality rates spiked not just from the diseases but also from secondary effects such as delayed treatments and overwhelmed systems. Vulnerable populations, including the elderly, the immunocompromised, and those with preexisting conditions, experienced higher morbidity and mortality rates, adding further pressure on healthcare systems.

To mitigate these challenges, Utilizing digital capabilities and technology breakthroughs is necessary in the provision of services in the public sector as stated by Mittal et al.'s (2023) and health sector in particular. Machine learning classifiers SVM, Decision tree, Naïve Bayes and Linear Regression, for the binary classification are increasingly being employed. (Gautam, Ahlawat, & Mittal, 2022). There was a significant increase in the use of

Editors: Ratnakirti Roy, Manish Kumar Thakur, and Anushree Raj
DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

telemedicine, which helped reduce the burden on physical healthcare facilities and allowed patients to receive medical advice remotely. Advanced patient monitoring technologies, such as sensors for saline level monitoring, autonomous bed adjustments, and accelerometers for pulse rate and temperature monitoring, provided real-time data to healthcare providers, enabling better patient management and early detection of complications. Data analytics and artificial intelligence (AI) were used to predict outbreaks, manage resources, and optimize patient care, analyzing trends and predicting patient needs to streamline operations within overwhelmed healthcare systems.Ransomware attacks can impact hospitals however with the help of AI the privacy threat can be prevented.(Gautam & Mittal, 2022). The strain experienced during pandemics underscores the need for robust healthcare infrastructure, sufficient medical supplies, and comprehensive support for healthcare workers. Lessons learned from past pandemics emphasize the importance of preparedness, advanced medical technologies, and efficient resource management to mitigate the impact of future health crises.

2 Literature Review

Current research emphasizes the need for innovative solutions to mitigate risks associated with staff inattentiveness, such as the development of IoT-based systems. (Kishore et al., 2022; Patel et al., 2023). These systems, equipped with sensors and alert mechanisms, enable real-time monitoring of saline levels, providing timely notifications to hospital staff when the saline is depleted. By addressing the potential dangers of backflow of blood and other associated risks, these solutions contribute significantly to enhancing patient care and safety in healthcare settings. (Omamageswari M et al., 2020). Bio-medical sensors interfaced with microcontroller were used to collect the data of heart beat rate, body temperature and body movement to get an overview of the present health condition of the patient during covid pandemic.(Amin et al., 2020).

Additionally, Covid positive patients were diagnosed with pneumonia as mentioned by Li Zhang et al.'s (2020) and a total of 14,364 participants from twelve studies satisfied the inclusion requirements. In patients with COVID-19, the combined prevalence of obesity was 32.0% (95% CI, 26%-38%, P <.001). In COVID-19 ICU patients, the prevalence of obesity was 37.0% (95% CI: 29%–46%, P <.001). The meta-analysis revealed that obesity was a significant risk factor for COVID-19 patients who required ICU care when comparing obese and non-obese patients (OR: 1.36, 95% CI 1.22-1.52, P <.001). It is anticipated that the Medi-Assist robot will be useful in strengthening the nation's healthcare system and containing the spread of COVID-19 in hospitals. (Maan, Madiwale, & Bishnoi, 2021). Future directions may involve further integration with existing healthcare infrastructure and leveraging data analytics to optimize monitoring processes and enhance overall patient outcomes, underscoring the ongoing evolution of monitoring practices to prioritize patient

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

well-being in healthcare environments.(Qadar et al., 2024).

The automatic bed positioning systems in healthcare is well-structured and comprehensive, covering the significance, key components, potential benefits, research gaps, and future directions of these systems. (Lamb & Madhe, 2017). The critical role of automatic bed positioning systems in healthcare, emphasizing their potential to enhance patient comfort, improve caregiver efficiency, and contribute to better patient outcomes. An algorithmic framework for in-bed position recognition, including preprocessing and convolutional neural networks, is proposed by Zhou et al.'s (2024). The implementation of smart saline level monitoring plays a vital role in healthcare by providing cost-effective, continuous surveillance of saline bottle levels. (More et al., 2021). This technology ensures that medical facilities maintain optimal saline levels without interruptions, thereby guaranteeing timely patient care. The primary objective is to prevent potential accidents and enhance patient safety. Continuous monitoring significantly reduces errors and accidents caused by depleted saline solutions, safeguarding patient well-being. The system aims to prevent adverse events related to saline shortages, ensuring a consistent and reliable supply of saline. (Sunil et al., 2020).

The smart saline monitoring system is designed to measure the weight of the saline bottle and accurately convert it into electrical signals, typically voltage. Through precise calibration, it translates variations in weight into specific voltage readings, ensuring the accurate capture of even minor changes in weight. Serving as the central processing unit for data analysis and communication, the system is responsible for receiving voltage signals from the load sensor and processing this information in real-time. The ESP32 microcontroller generates real-time messages based on the data received from the load sensor. These messages, containing crucial information about saline levels, are disseminated immediately to designated subscribers, such as doctors, nurses, and caretakers.(Ghosh et al., 2018).

The messaging and communication protocol is designed specifically for resource constrained devices, making it suitable for implementation in devices with limited processing power and memory resources. This ensures that the protocol operates efficiently without overburdening the constrained resources of the devices it supports.(Dilek et al., 2022). The protocol optimizes performance in scenarios where network connectivity may be limited or unreliable. Recognized for its reliability and robust message delivery mechanisms, the MQTT-S protocol ensures the consistent transmission of critical information. It provides a dependable solution for transmitting essential data, such as saline levels, without the risk of loss or delay. (Aledhari et al., 2022). This monitoring system enhances accessibility by supporting a wide array of devices commonly used by healthcare professionals. It enables seamless access to critical information about saline levels on devices such as smartphones, tablets, and laptops, optimizing versatility and flexibility in healthcare workflows.

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

Providing a user-friendly interface across different devices, the system allows healthcare professionals to easily access and interpret real-time messages about saline levels. It ensures that critical information is presented in a clear and understandable format, supporting efficient decision-making and intervention. The system also facilitates remote monitoring and telehealth services by allowing healthcare professionals to receive timely updates on saline levels regardless of their location. Adapting to the increasing trend of remote work and telehealth, it supports seamless communication and real-time monitoring in diverse healthcare environments.(Manvi Chauhan, 2023).

3 Methodology

The methodology can be explained through the following diagram:(see figure 1)

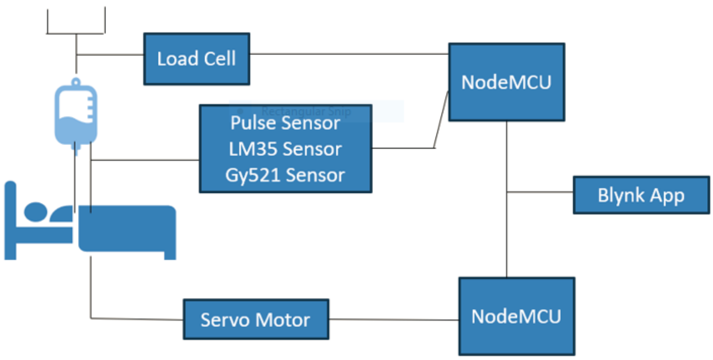

Figure 1. Methodology

3.1 Pulse Rate Monitoring:

- Continuous Heart Rate Tracking: The Pulse Sensor is utilized to continuously monitor the patient's heart rate, ensuring a continuous stream of real-time data on cardiac activity.
- Real-Time Data Provision: By employing the Pulse Sensor, the system delivers real-time information on the patient's cardiac activity, enabling healthcare providers to monitor heart rate changes immediately.
- Irregularity Monitoring: The Pulse Sensor's role includes monitoring for irregularities or fluctuations in the patient's pulse rate, allowing healthcare providers to identify any

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

concerning changes promptly.(see figure 2)

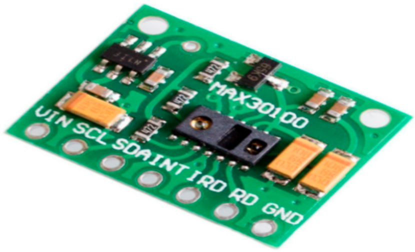

Figure 2. Pulse Sensor

3.2 Movement Detection

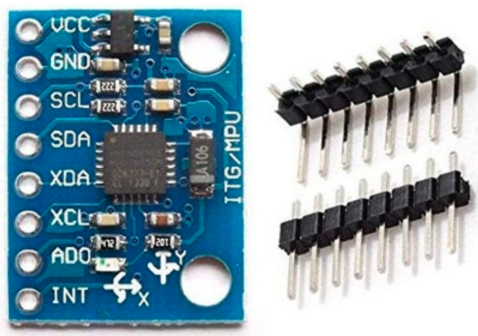

Figure 3. GY521 Sensor

- The GY521 Sensor is employed to detect even subtle body movements, providing a comprehensive view of the patient's physical activity levels, including small or nuanced motions that may not be easily observable.
- By utilizing the GY521 Sensor, the system can monitor a wide range of movements, enabling a detailed assessment of the patient's physical activity, which is crucial for assessing mobility and overall health status.
- The ability to detect subtle body movements using the GY521 Sensor (see figure 3)

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

offers valuable insights into the patient's health status, allowing healthcare providers to assess changes in activity levels and overall well-being.

3.3 Temperature Measurement:

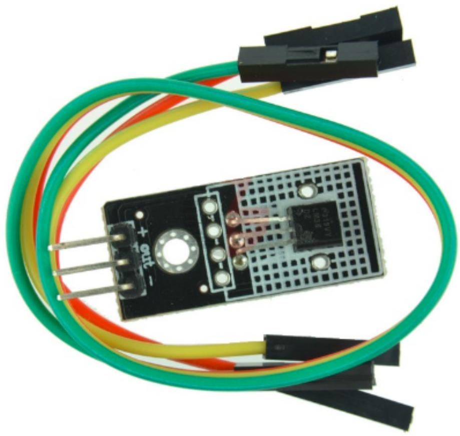

Figure 4. LM35 Sensor

- The LM35 Sensor is integrated into the system to provide precise and continuous monitoring of the patient's body temperature, ensuring accurate temperature readings for timely interventions and care adjustments.
- By utilizing the LM35 Sensor, the system can promptly detect elevated body temperatures, enabling healthcare providers to identify fever symptoms early and initiate appropriate treatments promptly.
- The LM35 Sensor (see figure 4) plays a crucial role in monitoring for hypothermia by detecting decreased body temperatures, alerting healthcare providers to potential hypothermia risks and enabling swift interventions to prevent complications.

3.4 Saline Level Monitoring:

The Saline level monitoring has been demonstrated in the following figure : (see figure 5)

- The Load Cell accurately measures the weight of the saline bottle, providing a precise and reliable assessment of the remaining saline level. This precision ensures accurate monitoring and management of saline supplies.

Editors: Ratnakirti Roy, Manish Kumar Thakur, and Anushree Raj
DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

- Utilizing the Load Cell enables real-time tracking of the saline bottle weight, facilitating continuous monitoring of saline consumption patterns. This data allows healthcare providers to anticipate refill needs proactively.
- Integration of the Load Cell incorporates an automated alert system that triggers notifications when the saline level reaches a predefined threshold. This system ensures timely replenishment and prevents shortages during patient care.

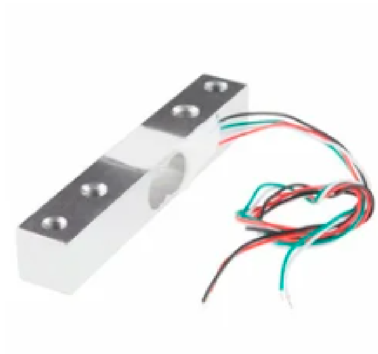

Figure 5. Load Cell

3.5 Automatic Bed Positioning:

- The Blynk-integrated bed positioning system enables personalized positioning adjustments, catering to individual patient comfort needs and preferences.
- The ability to set three preset positions through the Blynk App allows healthcare providers to quickly and easily adjust the bed to support various medical procedures, care activities, and patient comfort requirements.
- Integrated with the Blynk App, the bed's positioning system offers remote control capabilities, enabling healthcare providers to make necessary bed adjustments without physically manipulating the bed, thus enhancing efficiency and reducing physical strain.

The systematic integration of these components ensures comprehensive monitoring and an adaptive care environment for patients. The utilization of the Blynk App for bed adjustments not only simplifies the process but also enhances the efficiency and effectiveness of patient care management. (see figure 6).

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

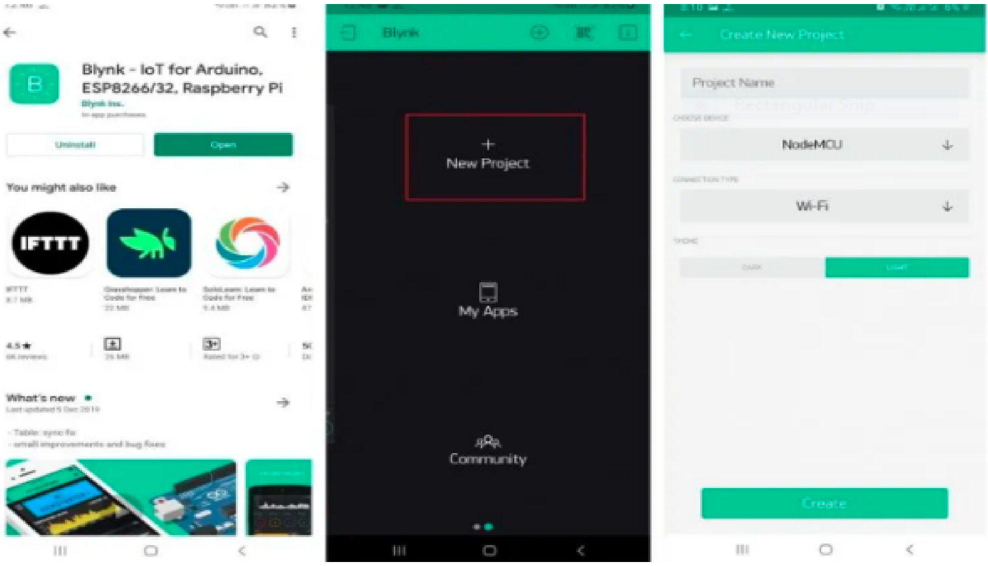

Figure 6. Automatic Bed Positioning

4 Results

The technological advancements in advanced patient monitoring within healthcare are revolutionizing patient care. By integrating a variety of sensors like load cells for saline level monitoring and the MAX30100 accelerometer for pulse rate monitoring, body movement tracking, and temperature sensing, healthcare providers can now access comprehensive and real-time patient data. One of the primary objectives is to prioritize patient safety through the immediate detection of anomalies and risks like infections using sophisticated sensor data processing, which triggers real-time notifications for healthcare staff. In tandem, there is a concerted effort to enhance patient comfort by incorporating features such as autonomous bed positioning driven by sensor inputs.

The Blynk smartphone app serves as a pivotal tool for remote monitoring and control, offering healthcare professionals crucial insights that optimize care delivery. This integrated approach not only propels healthcare processes towards efficiency and precision but also aims to ameliorate patient outcomes substantially in modern healthcare settings. Overall, the convergence of advanced sensor technologies is propelling healthcare delivery to new heights, setting a benchmark for elevated patient care standards.

Editors: Ratnakirti Roy, Manish Kumar Thakur, and Anushree Raj
DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

5 Conclusion

The integration of advanced sensor technologies in patient monitoring marks a significant advancement in modern healthcare delivery. By integrating load cells, autonomous bed positioning, and the MAX30100 accelerometer, healthcare systems can provide an elevated level of patient care. This comprehensive approach emphasizes patient safety through real-time notifications for healthcare staff and early hazard detection, enhancing infection control. Simultaneously, it prioritizes patient comfort by incorporating intricate monitoring features and auto bed positioning driven by sensor inputs. The utilization of the Blynk smartphone app as a central interface for remote monitoring and control not only provides real-time insights for healthcare professionals but also streamlines healthcare processes. This holistic approach optimizes patient outcomes and enhances care delivery efficiency, setting a new standard for modern healthcare settings.

References

Aledhari, M., Razzak, R., Qolomany, B., Al-Fuqaha, A., & Saeed, F. (2022). Biomedical IoT: Enabling Technologies, Architectural Elements, Challenges, and Future Directions. IEEE Access, 10, 31306–31339. https://doi.org/10.1109/ACCESS.2022.3159235

Amin, R., Saha, T. S., Hassan, M. F. B., Anjum, M., & Tahmid, M. I. (2020). IoT based medical assistant for efficient monitoring of patients in response to COVID-19. 2020 2nd International Conference on Advanced Information and Communication Technology, ICAICT 2020, 83–87. https://doi.org/10.1109/ICAICT51780.2020.9333448

Dilek, S., Irgan, K., Guzel, M., Ozdemir, S., Baydere, S., & Charnsripinyo, C. (2022). QoS-aware IoT networks and protocols: A comprehensive survey. International Journal of Communication Systems, 35(10). https://doi.org/10.1002/dac.5156

Gautam, S., Ahlawat, S., & Mittal, P. (2022). Binary and Multi-class Classification of Brain Tumors using MRI Images. International Journal of Experimental Research and Review, 29, 1–9. https://doi.org/10.52756/ijerr.2022.v29.001

Gautam, S., & Mittal, P. (2022). Comprehensive Analysis of Privacy Preserving Data Mining Algorithms for Future Develop Trends. International Research Journal of Computer Science, 9(10), 367–374. https://doi.org/10.26562/irjcs.2022.v0910.01

Ghosh, D., Agrawal, A., Prakash, N., & Goyal, P. (2018). Smart saline level monitoring system using ESP32 and MQTT-S. 2018 IEEE 20th International Conference on e-Health Networking, Applications and Services, Healthcom 2018. https://doi.org/10.1109/HealthCom.2018.8531172

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

Kishore, S., Abarnaa, K. P., Priyanka, S., Sri Atchaya, S., Priyanka, P. L., & Amala, J. J. (2022). Smart Saline Level Monitoring System using Liquid Level Switch Contactless Sensor, NodeMCU and MQTT-S. Proceedings - International Conference on Applied Artificial Intelligence and Computing, ICAAIC 2022, 1611–1614. https://doi.org/10.1109/ICAAIC53929.2022.9792849

Lamb, K., & Madhe, S. (2017). Automatic bed position control based on hand gesture recognition for disabled patients. International Conference on Automatic Control and Dynamic Optimization Techniques, ICACDOT 2016, 148–153. https://doi.org/10.1109/ICACDOT.2016.7877568

Li Zhang, Fan, G., Xu, J., Gu, X., Cheng, Z., Yu, T., Xia, J., Wei, Y., Wu, W., Xie, X., Yin, W., Li, H., Liu, M., Xiao, Y., Gao, H., Guo, L., Xie, J., Wang, G., Jiang, R., … Hu, Y. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet, 395(January), 497–506. https://doi.org/10.1016/S0140-6736(20)30183-5

Maan, R., Madiwale, A., & Bishnoi, M. (2021). Design and Analysis of 'Xenia: The Medi-Assist Robot' for Food Delivery and Sanitization in Hospitals. 2021 2nd Global Conference for Advancement in Technology, GCAT 2021. https://doi.org/10.1109/GCAT52182.2021.9587776

Manvi Chauhan. (2023). Emerging Trends in Telemedicine and Remote Patient Monitoring: Improving Access to Healthcare Services. International Research Journal of Basic and Clinical Studies. https://doi.org/10.14303/irjbcs.2023.42

Mittal, P., Jora, R. B., Sodhi, K. K., & Saxena, P. (2023). A Review of The Role of Artificial Intelligence in Employee Engagement. 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), 2502–2506. https://doi.org/10.1109/ICACCS57279.2023.10112957

More, A., Bhore, D., Tilak, M., & Gajanan D. Nagare. (2021). Iot Based Smart Saline Bottle for healthcare. International Journal of Engineering Research Technology (IJERT), 10(2), 406–410. https://doi.org/10.17577/IJERTV10IS060457

Omamageswari M, Priyadharshini M, Raisa A K, & Mariyasusmi F, F. A. K. (2020). Patient IV and Oxygen Control System using IoT. International Journal of Engineering Research and, 9(02). https://doi.org/10.17577/ijertv9is020402

Patel, R., Adhikari, M. S., Shukla, M. K., Payal, M., Kumar, P. M., & Verma, Y. K. (2023). Automatic Saline Monitoring System Using IoT. Proceedings - International Carnahan Conference on Security Technology. https://doi.org/10.1109/ICCST59048.2023.10474246

Qadar, S. M. Z., Naz, H., Shamim, S., Hashim, F., Ahmed, S., & Kumar Mehraj, S. (2024). Prevalence of Obesity and its Effects in Patients With COVID-19: A Systematic

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0

Review and Meta-analysis. Hospital Pharmacy, 59(3), 341–348. https://doi.org/10.1177/00185787231220318

Sunil, G., Aluvala, S., Ranadheer Reddy, G., Sreeharika, V., Sindhu, P., & Keerthana, S. (2020). IoT based saline level monitoring system. IOP Conference Series: Materials Science and Engineering, 981(3), 1453–1457. https://doi.org/10.1088/1757-899X/981/3/032095

Zhou, H., Sang, L., Luo, J., Wang, H., Feng, Y., Zhang, X., & Chen, L. (2024). Development of a multifunctional nursing bed system for in-bed position recognition and automatic repositioning. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 238(12), 5437–5454. https://doi.org/10.1177/09544062231223878

DOI:10.48001/978-81-966500-7-0-13 | ISBN: 978-81-966500-7-0