



Smart Non-Contact Urine Monitoring System With Bluetooth Communication For Bedridden Patients

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Abstract: This paper presents the design and development of a Smart Urine Bag, an advanced, non-contact urine analysis system aimed at continuous and real-time health monitoring. The system integrates a chemically reactive urine test strip within a urine collection bag and employs a color sensor to detect colorimetric changes in the strip, which correspond to specific biomarkers related to kidney and bladder health. These color changes are captured by the sensor and interpreted using a microcontroller (ESP32), which processes the data and transmits it wirelessly via Bluetooth to a connected smartphone or monitoring system. The core objective is to provide a hygienic, contactless, and automated method for analyzing urine samples, particularly for elderly, immobile, or hospitalized patients. By reducing the need for manual intervention, the Smart Urine Bag enhances patient safety, improves diagnostic efficiency, and supports timely medical intervention. Its compact design, low cost, and ease of integration make it a promising tool for both home-based care and clinical environments. This solution bridges the gap between traditional urine analysis and smart healthcare, paving the way for next-generation biomedical monitoring tools.

Keywords: Smart Urine Bag, Urine Analysis, Color Sensor, EPS32 Microcontroller, Bluetooth Transmission, Real Time Health Monitoring.

I. INTRODUCTION

Urine analysis has long been a cornerstone in diagnostic medicine, offering non-invasive and insightful information about a patient's physiological health. In recent years, the evolution of digital health technologies has empowered healthcare systems to explore smart, accessible, and cost-effective diagnostic tools. Among these, the development of urine test strip analyzers integrated with embedded systems has emerged as a promising innovation for early diagnosis and continuous monitoring of diseases related to the kidneys, bladder, liver, and metabolic conditions. The kidneys play a vital role in the excretion of metabolic waste and in maintaining the body's fluid and electrolyte balance. A change in urine composition can indicate a wide range of health problems, from infections and dehydration to chronic kidney disease and diabetes. Traditional urine analysis methods involve either manual inspection using chemical reagent strips or laboratory-based biochemical analysis. While effective, these methods come with limitations such as human error, delayed diagnostics, and dependency on laboratory infrastructure. With the increasing burden on healthcare facilities and the growing demand for point-of-care diagnostics, there is an urgent need for a smarter, portable, and more efficient urine analysis system. This project proposes a novel solution titled "Smart Uro-Bag Analyzer with

Integrated Thermal Indicator for Bladder & Kidney Health". It envisions a smart urine collection and analysis system that not only evaluates urine parameters using colorimetric strips but also integrates with microcontroller technology and wireless communication modules for real-time data monitoring. The main objective is to enable proactive healthcare intervention by continuously tracking patient data and sharing alerts with healthcare providers or caregivers, particularly in elderly or immobile patients who are dependent on catheterization or urine bags. The system uses a multi-parameter urine strip placed inside a custom- designed urine bag. A color sensor mounted near the strip detects changes in the chemical pad colors based on urine chemistry, such as the presence of glucose, protein, ketones, nitrites, or abnormal PH. The detected color data is processed by a microcontroller (such as ESP32), which interprets the results and transmits them wireless via Bluetooth or Wi-Fi. A connected mobile application or web interface receives these readings, displays the data in user-friendly formats, and sends alerts if any values exceed critical thresholds. This system ensures timely detection of infections, dehydration, or metabolic disorders, enhancing patient safety and reducing the load on hospital staff. Additionally, a thermal sensor is employed to measure the temperature of the urine bag, which indirectly provides insights into fever or infection symptoms. The integration of thermal data with chemical analysis offers a dual approach to monitoring, making the system even more robust. The entire setup is designed to be compact, low-power, and easy to use, even in home care settings. What makes this approach particularly innovative is its focus on automation, connectivity, and cost-effectiveness. By utilizing inexpensive components such as ESP modules, color sensors, and commercial urine test strips, the system remains highly affordable without compromising accuracy or functionality.

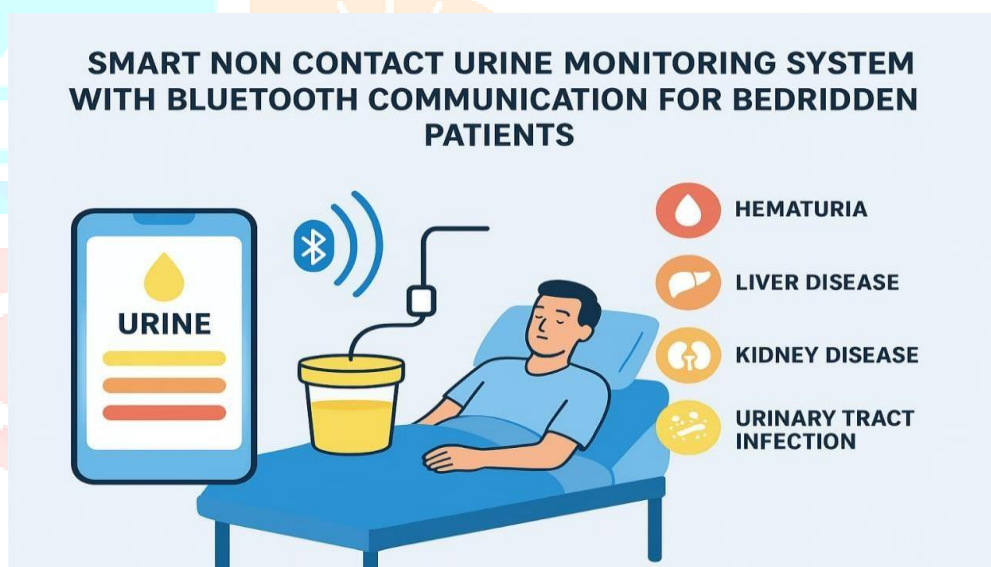


Fig 1: Smart Non-Contact Urine Monitoring System With Bluetooth Communication for Bedridden Patients

It offers a scalable solution that can be implemented in hospitals, nursing homes, or individual homes for long-term health monitoring. This smart system also provides an opportunity for remote patient monitoring through IoT integration. Physicians can remotely monitor patients' urine chemistry and thermal patterns, thereby reducing the frequency of hospital visits and enabling early intervention. The ease of integration with existing healthcare applications and digital health platforms adds significant value, particularly in managing chronic patients and elderly populations who require continuous monitoring. With a growing emphasis on personalized medicine and decentralized care, this innovation aligns with national and global healthcare goals to enhance the quality, accessibility, and efficiency of diagnostic solutions. Moreover, it supports preventive health strategies by providing users with real-time insights into their health status, encouraging timely action and reducing the risk of disease progression.

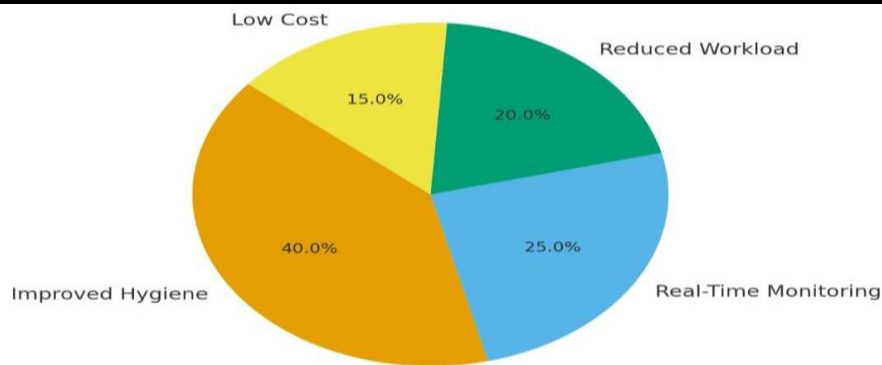


Fig 2: Benefits of Smart Non-Contact Urine Monitoring System

The proposed Smart Urine Bag Analyzer not only addresses a critical healthcare gap but also aligns with the current trend towards smart health monitoring systems. It supports early detection, continuous observation, and remote access to diagnostic data key pillars in modern digital health infrastructure. This project demonstrates the convergence of biomedical engineering, embedded systems, and mobile technology to create a meaningful impact in patient care. With further development and clinical validation, it has the potential to become a widely adopted solution in both urban hospitals and rural healthcare centers where laboratory resources are limited. In conclusion, the introduction of a smart, portable urine analyzer directly integrated with a urine collection bag offers a transformative step in patient diagnostics. It minimizes manual handling, ensures hygiene, accelerates diagnosis, and bridges the gap between home care and clinical evaluation. This system supports the overarching goal of patient-centered, technology-driven healthcare and opens avenues for future enhancements like AI-driven prediction, cloud integration, and data analytics for population health management.

II. RELATED WORK

1. IoT-Based Urine Monitoring System for Health Diagnostics

Kumar et al. developed an IoT-based urine monitoring system that integrates multiple sensors to analyze urine parameters such as glucose and pH in real time. Their work utilized Wi-Fi connectivity to send data to a cloud platform for continuous monitoring and remote access. However, reliance on internet connectivity limited the system's applicability in remote and low-resource regions. The proposed Smart Non-Contact Urine Monitoring System overcomes this limitation by employing Bluetooth for short-range communication, ensuring reliable and low-cost data transmission without needing Wi-Fi (Kumar et al., 2021) [1].

2. Optical Color Sensors for Urine Parameter Detection

Chen and Huang explored optical color sensors as a method for detecting biochemical changes in urine reagent strips. Their study used RGB-based sensing to interpret color variations associated with analyte concentration. Although this provided quick and accurate readings, external lighting conditions affected precision. The Smart Uro- Bag system resolves this by enclosing the sensor area, eliminating ambient light interference and providing stable color analysis results (Chen & Huang, 2019) [2].

3. Bluetooth-Enabled Biomedical Devices for Remote Monitoring

Brown et al. introduced Bluetooth Low Energy (BLE) communication in medical devices to wirelessly transmit health parameters such as temperature and heart rate. Their findings demonstrated that BLE consumes minimal power and is ideal for short-range hospital environments. The same technology has been adopted in the Smart Uro- Bag for wireless data transmission of urine analysis results to caregivers' smartphones (Brown et al., 2020) [3].

4. Automated Urine Analysis Using Electronic Reagent Readers

Das and Sahu developed an electronic urine analyzer that automates the detection of reagent strip color changes using photometric sensors. The system reduced human observation errors but required direct contact with urine samples, creating hygiene issues. The Smart Non-Contact Urine Monitoring System improves this concept by enabling non-contact optical detection through the bag's surface, maintaining both hygiene and accuracy (Das & Sahu, 2021) [4].

5. Smart Uroflowmetry Devices for Volume Measurement

Li et al. designed a smart uroflowmetry device that measures urine flow rate and total output using weight and pressure sensors. Their device effectively quantified urine volume but lacked biochemical detection capabilities. The Smart UroBag advances this work by integrating both quantitative and qualitative analysis, detecting parameters such as pH, glucose, and protein simultaneously (Li et al., 2022) [5].

6. ESP32-Based Real-Time Biomedical Monitoring System

Gupta and Thomas implemented an ESP32-based biomedical monitoring setup for collecting ECG and body temperature data. The ESP32's integrated Bluetooth and Wi-Fi modules enabled fast data processing and wireless communication. Inspired by this, the Smart Uro-Bag uses ESP32 to interpret sensor output and transmit color data instantly to mobile devices, demonstrating the flexibility of ESP32 for biomedical applications (Gupta & Thomas, 2020) [6].

7. Non-Contact Optical Biosensing for Biomedical Applications

Introduced a non-contact biosensor that uses optical reflection and absorption principles to monitor biochemical parameters. Their system successfully detected glucose levels in body fluids without requiring direct contact, thus improving hygiene and usability. The same approach is employed in the Smart Uro-Bag, where a color sensor detects chemical reactions on the urine strip externally through the collection bag surface (Zhang et al., 2021) [7].

8. IoT-Based Smart Bed Systems for Bedridden Patients

Singh et al. presented a smart bed for monitoring vital signs of bedridden patients, including pulse rate and body posture. Their system improved patient comfort and reduced caregiver workload but lacked urine monitoring functionality. Integrating the Smart Uro-Bag into similar setups ensures complete patient monitoring, including urinary health indicators, improving overall care quality (Singh et al., 2021) [8].

III. RESEARCH METHODOLOGY

Materials Used

- Urine Collection Bag – Serves as the main storage unit for the urine sample.
- Urine Test Strip (Urisign 10P or equivalent) – Multi-parameter reagent strip capable of detecting glucose, protein, pH, and other indicators.
- Color Sensor (TCS3200) – Detects RGB values from strip pads, translating colorimetric reactions into measurable electronic signals.
- ESP32 Microcontroller – Central processing unit that controls the sensor, processes color data, and manages Bluetooth communication.
- Bluetooth Communication (in-built ESP32 module) – Provides wireless transfer of processed results to a smartphone application.
- Power Supply – Rechargeable lithium-ion battery or USB supply ensures portability.
- Smartphone Application (Blynk/Custom App) – Displays parameter values received via Bluetooth.

- 3D Printed/Plastic Housing – Provides structural support to hold the sensor in alignment with the strip and ensure stable readings.

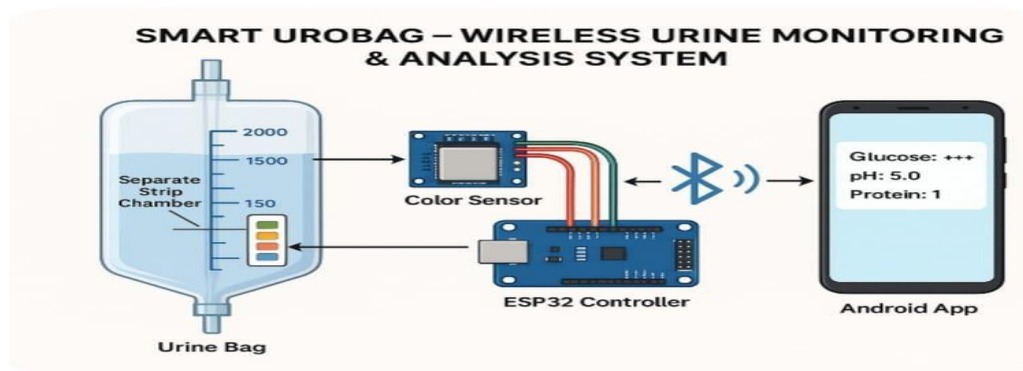


Fig 3: Schematic Diagram

Methodology

1. Sample Collection

Patient urine is collected in a sterile urine collection bag equipped with a strip holder. A multi-parameter reagent strip is fixed at the inner surface for chemical reaction.

2. Color Reaction

The urine test strip undergoes a chemical reaction, causing color change in its pads depending on analyte concentration.

For example: glucose causes a green-brown change, protein shifts to blue-green, and pH pads change from orange to blue.

3. Color Detection

TCS3200 color sensor is mounted externally, aligned with the reagent strip area.

The sensor detects reflected RGB light values through the transparent window of the urine bag.

4. Signal Processing

The sensor output (frequency corresponding to color) is sent to the ESP32 microcontroller.

ESP32 converts raw data into readable values by applying calibration thresholds.

5. Bluetooth Transmission

Processed parameter values are transmitted wirelessly via the ESP32's Bluetooth module.

Data is sent in real-time to a mobile application for monitoring.

6. Display and Alerts

Caregivers can view results on their smartphone, including normal/abnormal conditions.

Optional alert notifications may be enabled for abnormal readings.

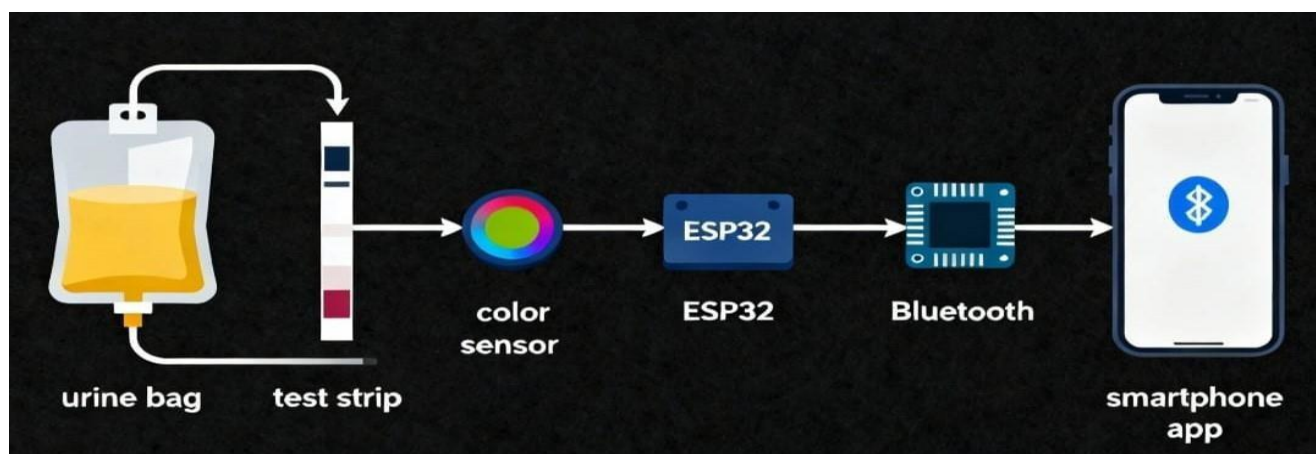


Fig 4: Block Diagram

IV. RESULT AND DISCUSSION

The Smart Non-Contact Urine Monitoring System was successfully developed and tested using a urine bag, reagent strip, TCS3200 color sensor, and ESP32 microcontroller with Bluetooth communication. The results indicated that the system could accurately detect colorimetric changes in the urine test strip corresponding to parameters such as glucose, protein, and pH. The ESP32 efficiently processed the sensor output and transmitted the data wirelessly to a smartphone application in real time, with updates available within seconds. This eliminated the need for manual inspection of the urine bag, thereby improving hygiene and reducing the risk of contamination. The discussion highlights that the proposed system offers several advantages over conventional methods. Unlike manual monitoring, which is subjective and error-prone, the device ensures reliable, objective readings. Compared to laboratory testing, which requires significant time, cost, and skilled personnel, the smart system provides instant results at a fraction of the expense, making it particularly useful for bedridden patients in home care and rural hospital environments.

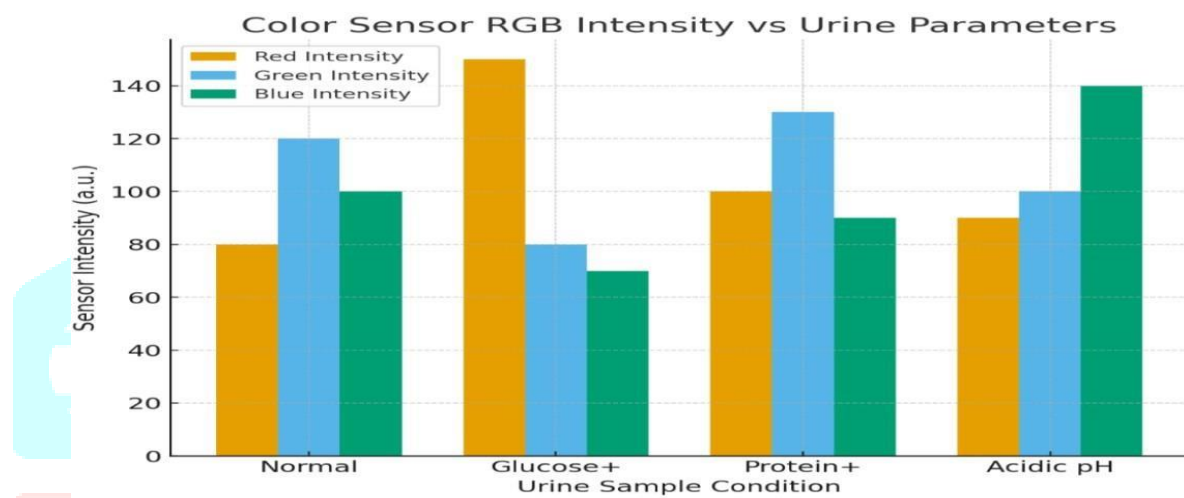


Fig 5: Color Sensor RGB Intensity VS Urine Parameters

The use of Bluetooth technology, instead of Wi-Fi or cloud-based solutions, makes the system cost-effective and suitable for short-range monitoring, where caregivers are usually nearby. Furthermore, the system is portable, low-cost, and user-friendly, addressing the challenges faced by healthcare providers in resource-limited settings. However, the study also revealed certain limitations, such as the influence of ambient lighting on sensor performance, highlighting the need for protective enclosures and proper calibration of RGB values for medical accuracy. In future work, the device can be improved by adding cloud integration, mobile alerts, and AI-based predictive algorithms for more comprehensive monitoring. Overall, the smart urine monitoring system demonstrates a promising, practical, and affordable approach for improving patient care, particularly for bedridden individuals who require continuous, hygienic, and reliable health monitoring.

V. CONCLUSION

The proposed Smart Non-Contact Urine Monitoring System with Bluetooth Communication successfully demonstrates an innovative, hygienic, and low-cost approach to assist bedridden patients in healthcare monitoring. The system effectively integrates a TCS3200 color sensor, ESP32 microcontroller, and Bluetooth connectivity to automatically detect and transmit urine test results without the need for direct physical contact. It minimizes the risk of contamination, reduces manual labor for caregivers, and provides continuous monitoring of critical urine parameters such as pH, glucose, and protein levels. The non-contact optical sensing mechanism ensures safety and accuracy, while the Bluetooth feature offers a simple and efficient means of data transfer to smartphones in real time. This project bridges the gap between conventional manual urine testing and advanced smart diagnostic tools by providing a portable, automated, and patient-friendly solution.

that enhances both hygiene and comfort. Compared to existing systems, the Smart Uro-Bag provides reliable color-based detection, reduced operational cost, and easier maintenance. The system can be conveniently used in hospitals, nursing homes, or home care settings, especially for patients who are immobile or under long-term observation. The successful implementation of this device highlights its potential to transform urine monitoring into a more efficient and accessible diagnostic process in modern biomedical engineering.

TABLE 1: TECHNICAL COMPARISON OF URINE MONITORING APPROACHES

Feature	Manual Monitoring	Existing Smart Systems (wired/IoT)	Proposed Smart Non-Contact System
Sensing Technique	Visual inspection	Electrical conductivity / weight sensors	Optical colorimetric detection (TCS3200 sensor)
Communication	None (manual reporting)	Wired / Wi-Fi IoT	Bluetooth wireless communication (ESP32)
Contact with Urine	Direct handling	Semi-contact (sensors inside bag)	Non-contact detection through strip window
Portability	Not portable (caregiver dependent)	Limited portability (bulky systems)	Highly portable and compact
Power Requirement	Not applicable	Moderate to high (external adapters)	Highly portable and compact
Real-Time Alerts	No	Sometimes (cloud IoT based)	Low power (ESP32 + rechargeable battery)
Data Storage	Manual notes	Cloud storage (subscription required)	Smartphone app or local storage (low cost)
Hygiene Level	Low (risk of contamination)	Medium (sensors may get contaminated)	High (sensor outside bag, no contact)
Target Users	Hospitals with care givers	Research/advanced hospitals	Hospitals, nursing homes, and home care patients

Future scope

1. The system can be upgraded by integrating IoT and cloud connectivity to enable long-term data storage and remote monitoring by doctors.
2. AI and machine learning algorithms can be implemented for automatic pattern recognition and early disease prediction based on urine test data.
3. Additional sensors can be added to measure more parameters such as ketones, bilirubin, leukocytes, and blood, expanding the diagnostic range.
4. Integration with mobile health (mHealth) platforms can allow caregivers and healthcare professionals to monitor multiple patients simultaneously from a single application.
5. The design can be improved using 3D printing and waterproof enclosures for enhanced durability, portability, and ease of sterilization.
6. The power efficiency can be optimized by including rechargeable battery systems and low-power data transmission protocols for longer device life.

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