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WEARABLE NON-INVASIVE OPTICAL MONITORING FOR BLADDERDYSFUNCTION–IN CONTINENCE AND ENURESIS

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ABSTRACT

This study proposes a novel real-time monitoring system designed to continuously assess urinary bladder volume and promptly alert healthcare providers when the bladder is filled beyond normal limits. The system utilizes noninvasive ultrasonic sensors and advanced signal processing algorithms to measure bladder volume accurately. The collected data is transmitted wirelessly to a centralized platform accessible to medical professionals. Key features of the monitoring system include real-time data visualization, trend analysis, and intelligent alerting mechanisms. By employing machine learning algorithms, the system can adapt to individual patient patterns and provide personalized alerts, reducing false alarms and enhancing the overall accuracy of bladder volume assessments. The alerts are designed to intimate healthcare providers, facilitating timely intervention and preventive measures. The implementation of this monitoring system aims to improve patient care by addressing issues related to urinary bladder dysfunction, such as overfilling or inadequate emptying, which can lead to various medical complications. The proposed system has the potential to enhance patient outcomes, streamline healthcare processes, and contribute to the overall improvement of urological care.

INTRODUCTION

Over 200 million people worldwide suffer with urinary incontinence (UI), which is defined as the involuntary flow of pee. UI has significant socio-psychological and physiological ramifications. The illness not only makes daily tasks difficult but also significantly lowers quality of life, resulting in psychological discomfort like anxiety and sadness as well as feelings of shame and social isolation. Because neurogenic bladder dysfunction (NBD) is associated with serious neurological diseases such as spina bifida and spinal cord injuries, it stands out among the different causes of Ulas one of the most severe. NBD is characterised by a breakdown in the neurological system's ability to communicate with the bladder, which leaves the bladder feeling and controlling less. Serious physiological consequences, including over distension of the bladder, urine retention, and in severe cases, kidney damage, may result from this (Macnab et al., 2012; Perez et al., 2022). These can set off chronic health problems. Oftentimes, managing NBD calls for a multidisciplinary strategy. Pharmacological treatments and intermittent catheterisation (IC) are used in combination for the treatment of about 90% of affected persons. This strategy is essential for managing the symptoms of NBD and averting more issues. Specifically, IC helps lower the risk of bladder over distension, a common and potentially harmful side effect of NBD. Long-term catheteruse is not without its difficulties, though; among them are heightened risks of urinary tract infections (UTIs) and the physical discomfort that comes with having a catheter inserted repeatedly (Feneley et al., 2015; Hidas et al., 2017). Urinary incontinence comes in different types, each with its own unique pathophysiological causes. One of the most prevalent types of incontinence is urge incontinence, which is defined by an abrupt, strong urge to urinate that frequently results in leaking before using the restroom. Overactive bladder (OAB), which can be brought on by a number of conditions including obesity, low oestrogen levels after menopause, infections, weak pelvic floor muscles, and nerve damage, is commonly linked to this illness. OAB symptoms can also be made worse by lifestyle choices like drinking alcohol or coffee, consuming particular meals, and taking particular medications (Abelson et al., 2019;Aoki et al., 2017).

Stress In continence:

Exercise, laughing, sneezing, coughing, and other physical activities that raise intra-abdominal pressure can cause stress incontinence, another common type of UI. Weakened pelvic floor muscles are usually the cause of this kind of incontinence because they are unable to support the bladder and urethra sufficiently. Men and women who have had prostate surgery or who are recently gave birth are more likely to experience stress incontinence (Cervigni & Gambacciani, 2015; Vo & Kielb, 2018). The sphincter muscles' capacity to maintain closure is diminished when the pelvic floor muscles weaken, which can happen as a result of childbirth, surgery, or ageing. This increases the risk of urine leakage.

Over flow In continence:

Another major worry is overflow incontinence, which is defined as the frequent or continuous leaking of pee as a result of an overfilled bladder. This disorder is frequently brought on by an inability to completely empty the bladder, which can be brought on by weak bladder muscles or obstructions such an enlarged prostate in men. People who have overflow incontinence continuously leak little volumes of pee; it's like a juice bottle that overflows but spills the contents gradually instead of all at once. Because it frequently goes undiagnosed until serious bladder injury has occurred, this type of incontinence is especially difficult to treat (Gratzke et al., 2015; Wilson et al., 2022).

Mixed In continence:

The management of mixed incontinence, which combines urge and stress incontinence, is very challenging since it necessitates addressing several underlying problems. This kind of incontinence is typical among the elderly and frequently calls for a thorough assessment in order to determine the main symptoms and create a treatment plan that works. Treatments for one form of symptoms may worsen the other, making the cohabitation of stress and urge symptoms more difficult to manage (Aoki et al., 2017).

Since urine incontinence can take many different forms, a precise diagnosis and individualised treatment programs are crucial. Urinary incontinence can now be diagnosed and treated more successfully because to developments in ambulatory urodynamic devices and urodynamic monitoring. These devices, which enable ongoing bladder function monitoring in real-world situations, offer priceless insights into the underlying causes of incontinence, resulting in therapies that are more precisely targeted (Abelson et al., 2019; Fournelle et al., 2021).

In conclusion, urine in continence is a serious health issue that necessitates a multimodal approach to treatment, especially when linked to neurogenic bladder dysfunction. Improvements in therapy approaches and diagnostic technologies could potentially improve the prognosis for those suffering with this crippling illness. Urinary incontinence sufferers can live better lives if non-invasive monitoring technologies and individualised treatment regimens are further researched and developed.

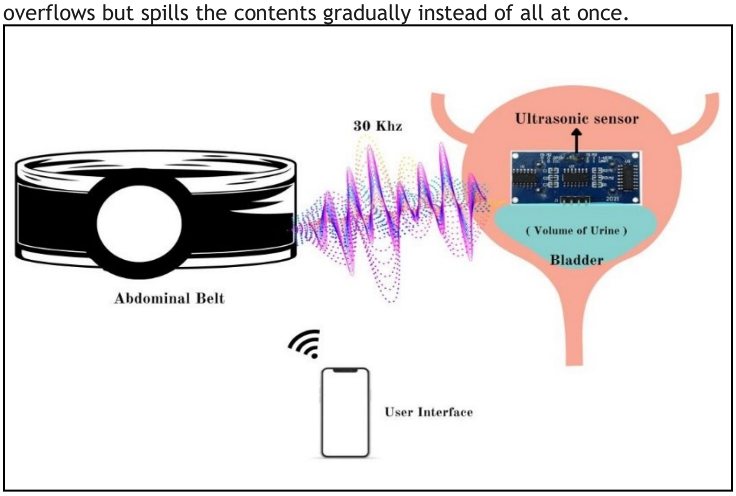

Figure1: Wearable Non-Invasive Optical Monitoring for BladderDys function

OBJECTIVE

The goal is to develop a non-invasive, real-time technology that continuously measures the volume of the bladder. This device would use sensors to monitor bladder fullness and provide intelligent alarms. When bladder volume rises above a user specified threshold, these notifications would warn users and, if needed, medical professionals, indicating that urination is important to avoid overflow incontinence or possible urinary tract problems. This technology seeks to enhance overall urinary health, maybe less catheter dependency, and provide users more control over their bladder function by facilitating quick intervention. The notifications' intelligence component might also take into account personal urgency levels or combine them with other health data to provide a more complete picture.

PROPOSED SYSTEM

WIRELESSD AT A TRANSMISSION:

The collected data will be transmitted wirelessly to a centralized platform, allowing for seam less and continuous monitoring. This ensures that healthcare professionals have access to real-time information about bladder volume without the constraints of physical connections.

ADVANCED SIGNAL PROCESSING ALGORITHMS:

Sophisticated signal processing algorithms will be employed to analyze the sensor data accurately. These algorithms will provide precise measurements of bladder volume and can adapt to individual patient characteristics, enhancing the system's reliability.

REAL-TIMEDATAVISUALIZATION:

The proposed system will offer intuitive and user-friendly realtime data visualization tools. Healthcare providers can monitor bladder volume trends, fluctuations, and anomalies, enabling quick and informed decision-making.

METHODOLOGY

The use of non-invasive ultrasonic sensors to continuously monitor the volume of the urine bladder in real-time offers a revolutionary way to enhance urological care. Low-profile ultrasonic transducers are used in this novel technology, which uses a forward-looking pulse-echo technique on the lower abdomen. The technology ensures discretion and user-friendliness by monitoring bladder volume and sending timely alerts to the patient using a gentle vibration motor. With the help of a wireless Wi-Fi IoT module, doctors, caretakers, or family members may access this securely saved data in the cloud, ensuring that everyone engaged in the patient's care is informed and able to act quickly.

Through the integration of a machine learning algorithm, the sensor system gains the ability to recognize and adjust to the unique patterns of each patient, resulting in personalized warnings that are accurate and customized to meet the patient's individual needs. The quality of life for those with bladder-related problems, such as urine incontinence, can be considerably improved by this proactive and responsive kind of therapy, which has the potential to drastically improve patient outcomes.

Additionally, depending on the demands of the user, the choice between edge and cloud computing systems allows flexibility. For patients and carers who need to monitor the condition remotely, cloud computing offers scalable storage and convenient data access from any location. Edge computing, on the other hand, has the benefit of processing data locally on the device, providing improved data security and privacy—an important factor to take into account for sensitive health information.

In summary, the management of urine incontinence could be completely transformed by combining ultrasonic sensor technology with Internet of Things-based intelligent warnings. Ultrasonic sensors are more accurate and dependable than capacitive sensors, and the option to personalize alerts and link them with other monitoring systems offers a complete solution for patient care. Patients and healthcare professionals may make sure the technology meets their unique needs by selecting the right IoT platform, which balances scalability, accessibility, security, and privacy to produce the greatest results.

SYSTEMHARDWAREAND SOFTWARE DESIGN

There are two components to the bladder volume measurement and warning system. The wearable ultrasonic measurement device is one of them. This part's primary duties include processing ultrasonic echo, creating and receiving ultra sonicpulseecho, calculating bladder volume, and sending estimated volume data via WIFI wireless connection module. The alarm unit is an additional component that is responsible for gathering volume data, establishing a personal bladder volume threshold, and sounding an alert when the threshold is crossed.

ULTRA SOUND BLADDER VOLUME MEASUREMENT

The ultrasonic pulse sending and receiving circuit, the Target Device ESP8266-12E, the high-speed AD acquisition circuit, the PHP database, and the WIFI module are the five main elements of the ultrasound bladder volume measurement unit. The circuit is made to be inexpensive. One could just drive the transmitting transducer straight from the PIC. For large things, the 5volt drive can provide a respectable range, but it may have trouble detecting tiny objects. I made the decision to approach this level because the transducer can withstand up to 20 volts of drive. With avoltageofroughly16 volts, aMAX232 IC, which is typically utilised for RS232 communication, is the perfect driver. A traditional two-stage op-amp circuit powers the receiver. This is nearly the 25 maximum gain that the LM1458 can achieve. The amplifier's output is connected to an LM311 comparator. Hysteresis is provided by a tiny quantity of positive feedback, resulting in a clear, stable output.

ULTRA SONIC DISTANCE SENSOR

By giving off a brief ultrasonic burst and then "listening" for the echo, the sensor finds objects. A brief 40 kHz (ultrasonic) burst is released by the sensor, which is controlled by a host microcontroller (triggerpulse).The sensor that was tested in the Parallax lab and coupled to a BASIC Stamp micro controller module is the basis for the test data on the subsequent pages. At the same height as the sensor, the target was always centred.

HARDWARE COMPONENTS

The proposed methodology includes a simple electronic system that includes the following components: Ultrasonic sensor, vibration motor, Node MCU, WIFI module, and PHP Database.

ULTRA SONIC SENSOR

When sound waves are emitted towards an object, an ultrasonic sensor detects the reflected waves to calculate the item's distance. (Photo via Getty Images)) An electronic device known as an ultrasonic sensor uses ultrasonic sound waves to determine an object's distance and then transforms the reflected sound into an electrical signal. The speed of ultrasonic waves surpasses that of audible sound, which is sound that is perceptible to humans. The transmitter, which uses piezoelectric crystals to produce sound, and the receiver, which detects sound after it has travelled to and from the target, are the two primary parts of ultrasonic sensors.

VIBRATION MOTOR

This vibratory motor without a shaft is ideal for non-audible indicators. Use for a variety of purposes to alert the wearer when a status modification has occurred. The casing provides protection for all moving parts. Designed to operate between 2.5V and 3.8V, these units tremble violently at 3V. When the device is pocketed or fixed to a PCB, it vibrates subtly but clearly. Reinforced connection wires and a 3M adhesive backing are included with this premium item.

NODEMCU

For storing data and programs, Node MCU contains 4MB of Flash memory and 128 KB of RAM. The low-cost, cutting-edge NODEMCU ESP8266 V3 Lua CH340 Wifi Development Board offers rapid WiFi technology. Advanced, well-developed LUA-based technology now a days. With all of the resources at its disposal, it functions as a cohesive unit. It may be easily added to your current Arduino projects or to any development board with appropriate I/O pins.

WIFI MODULE

With its inbuilt TCP/IP protocol stack, the self-contained SOC ESP8266 WiFi Module allows any microcontroller to connect to your WiFi network. Either an application can be hosted on the ESP8266, or it can delegate all WiFi networking tasks to another application processor. Since each ESP8266 module has an AT command set firmware pre-programmed, all you have to do is connect it to your 22 Arduino device toget almost the same amount of WiFi functionality as a WiFi shield—and that's right out of the box! The ESP 8266 module is a very affordable board with a sizable and continuously expanding community. Through its GPIOs, this module may be integrated with sensors and other application-specific devices with minimal development required up front and minimal loading during runtime because to its robust onboard processing and storage capabilities. Because of its high level of on-chip integration, it only requires a small amount of external circuitry, including the front-end module, which is made to take up little space on the PCB.

PHP APP DATABASE

PHP code can be used alone with HTML code or in conjunction with different web frameworks and templating engines. PHP interpreters, which are often implemented as native web server modules or common gateway interface (CGI) executables, are responsible for processing PHP code. The web server delivers the output to its client—typically a portion of the created web page—after the PHP code has been interpreted and run.

FUTURE SCOPE AND DISCUSSION

The potential for enhancing patient care with non-invasive bladder monitoring for incontinence is encouraging. Continuous monitoring is made possible by technologies such as wearable sensors, ultra sono graphy, and smart textiles, which provide useful information for individualized treatment regimens. This method improves early identification, makes prompt interventions easier, and helps with incontinence issue management. By incorporating these technologies into medical procedures, bladder-related issues can be resolved n away that is more effective and convenient for patients. This aids in the comprehension of the physiological alterations linked to bladder function and offers important information for the diagnosis and treatment of incontinence.

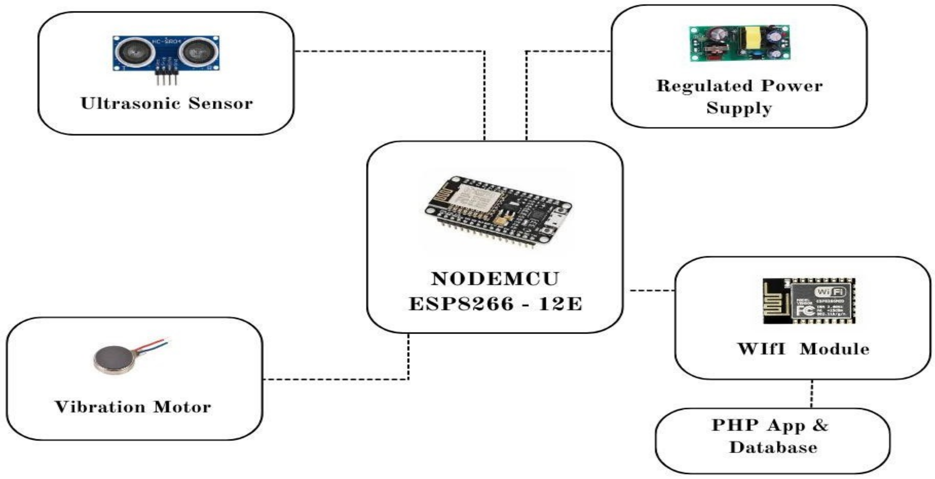

Figure2:Block Diagram

SAMPLE TABULATION

Sample Data Table for Wearable Non-Invasive Optical Monitoring for BladderDysfunction.

S.No	Time stamp	Water Level(ml)	Notification
1.	21.07.2024 08:30PM	150 ml	“Low water level detected”
2.	21.07.2024 08:40PM	300 ml	“Moderate water level detected”
3.	21.07.2024 08:50PM	450 ml	“High water level detected”
4.	21.07.2024 09:00PM	600 ml	“Bladderfull-Urgentaction!”

Table1: Sample Tabulation Timestamp: The time when the reading was taken.

Water Level (ml): The level of water in the fake bladder (representing urine volume).

Notification: The message sent via WiFi to the PHP app end database.

CONCLUSION

Urinary bladder monitoring can be performed using different types of sensors, including capacitive and ultrasonic sensors. Capacitive sensors measure the change in capacitance due to the presence of urine, while ultrasonic sensors use sound waves to detect the level of urine in the bladder. Ultrasonic sensors have several advantages over capacitive sensors (Shin, S. C. et al. 2017). They are more accurate and reliable, as they can detect the exact level of urine in the bladder, while capacitive sensors can only detect the presence or absence of urine. Ultrasonic sensors are also more cost effective, as they can be used for a longer period without needing replacement. Furthermore, ultrasonic sensors are less prone to false alarms, as they are not affected by external factors such as humidity or temperature. Intelligent alerts are generated by IoT systems to notify caregivers or patients of any abnormalities in urinary bladder monitoring. These alerts can be in the form of sound or visual notifications, depending on the user's preference. Sound alerts are more effective in noisy environments, while visual alerts are more suitable for users with hearing impairments. IoT systems also offer customization options, allowing users to set the threshold for alerts and adjust the frequency of notifications (Lin, M. et al. 2023). Integration with other monitoring systems, such as heart rate monitors or blood pressure monitors, can also improve the accuracy and reliability of the alerts.

Conflict of interest

AllAuthorshavenoconflictofinterestinthispaper.Aswehavenoconflicts, we can disclose the paper.

Source of funding

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Ethical clearance

Any of the authors’ human subjects' investigations are included in this article.

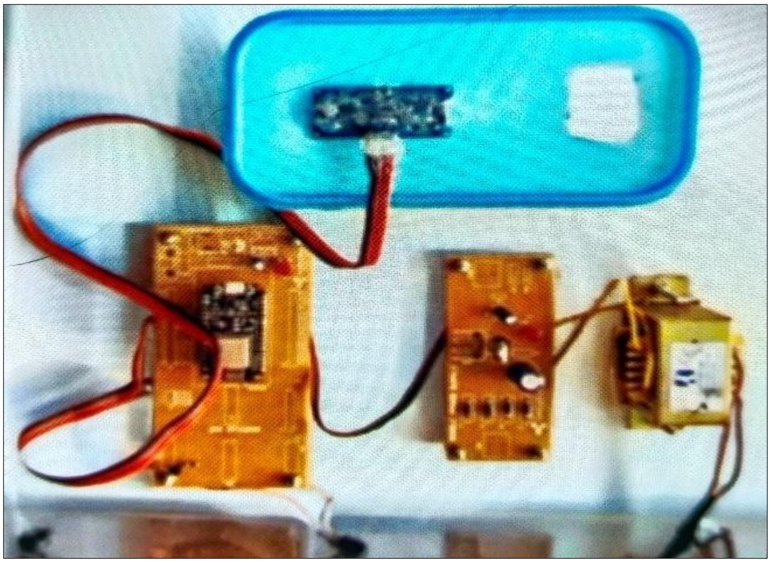

Figure3: Prototype model

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