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ENHANCING MOBILITY WITH IOT-BASED AUTONOMOUS WHEELCHAIR

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ABSTRACT:

The shortage of healthcare workers and continuous influx of patients have significantly increased workloads in hospitals. Concurrently, there is an increasing number of people with disabilities, resulting in a higher need for wheelchairs. Yet, many hospitals continue to rely on traditional, manually operated wheelchairs. As a result, disabled patients often face prolonged waits for assistance from hospital staff to reach their intended destinations. To address hospital issues, the idea of autonomous wheelchairs, known as autonomous robotic wheelchairs (ARWs), has been proposed and developed. In contrast to traditional wheelchairs, ARWs integrate advanced features, including obstacle detection and avoidance, local path mapping through line-following technology, and user-friendly interactions. Patients in developing countries, including the Kurdistan region of Iraq (KRI), rely on hospital workers for transportation, which poses difficulties, especially during emergencies, such as overcrowding, delays due to a lack of available porters, etc. Implementing ARWs would significantly reduce these issues. Thus, the main aim of this study is to develop ARWs using technologies like Arduino and sensors to enhance hospital efficiency and reduce reliance on porters, potentially transforming patient mobility and care in healthcare facilities. The testing results of the proposed system indicate that its implementation will greatly assist hospitals in addressing various issues, including those previously mentioned. In addition, it will enhance hospitals' intelligence and autonomy.

KEYWORDS: Autonomous Robotic Wheelchair (ARW), IoT Technology, IoT-based Sensors, Autonomous Navigation, Line-following Method

1. INTRODUCTION

Hospitals provide a variety of services, including external consultations, examinations, analyses, and surgeries that require transporting patients to those services. This deserves some attention, particularly in cases involving people with limited mobility, such as individuals with disabilities, lower limb injuries, or the elderly. Currently, non-specialized patient transporters are typically in charge of managing patient transportation in hospitals (Baltazar *et al*., 2021), which can occasionally result in a negative experience. As a result, Baltazar *et al*. (2021) and Wang *et al*. (2020) stated that this task could be more efficiently accomplished using autonomous wheelchairs. This technique might reduce delays and avoid failures caused by understaffing in patient transportation.

Nowadays, the development and integration of autonomous technology have risen across various sectors, aiming to enhance healthcare services and enable those with impairments (Lakshmi *et al.,* 2022). Among these developments, ARWs stand out as a transformative innovation, offering unprecedented mobility for those with mobility impairments. In addition, as stated by several scholars (Baltazar *et al*., 2021; Sahoo & Choudhury, 2023; Sahoo & Choudhury, 2024), *ARW* is a mobility aid equipped with various sensors, artificial intelligence (AI), and robotics, which enables independent navigation. It autonomously detects obstacles, plans routes, and adjusts to its environment, benefiting individuals with impairments. This invention encourages more independence in routine hospital tasks by reducing the need for manual assistance.

In KRG hospitals, manual operation of wheelchair is common, requiring staff assistance for patient transfers between sections. This results in problems like overcrowding, especially during emergencies, and patient fatigue. Additionally, non-specialized staff handle transfers, posing further challenges. According to many studies, the use of ARWs might resolve these issues by ensuring patients reach their destinations quickly and reduce the need for staff help. Bearing these ideas in mind, this study proposes an ARW designed to transfer patients within hospital sections autonomously, aiming to address the mentioned issues. The ARW utilizes various sensors, including ultrasonic and infrared (IR), to detect obstacles and follow predefined environment lines, enabling autonomous movement. Moreover, Arduino microcontroller, along with other hardware components, are employed to manage and control the sensors and ARW's movement.

The rest of the paper is structured as follows: In section 2, a number of related works for ARWs are presented. The

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construction methodology and ARW's operations are discussed extensively in Section 3. In addition, the section provides detailed information on the software and hardware realizations for ARW development. In Section 4, the results obtained are presented along with detailed discussions. Finally, the conclusions of the study and future works are explored in Section 5.

2. RELATED WORKS

So far, various autonomous wheelchairs have been proposed. Nevertheless, they still necessitate improvements to offer the best assistance or solution to their users.

In 2019, Alkhalid and Oleiwi (2019) introduced a smart autonomous wheelchair that operates through voice commands. The main goal of this system was to provide various features to assist and enhance the mobility of individuals with disabilities. It utilizes pre-defined voice commands and GPS technology for navigation and localization. Although the system offers only basic features compared to more recent studies, it can be noted that they successfully designed and implemented the system based on their results. To improve wheelchair control, several researchers have proposed various methods aimed at enhancing mobility and movement precision. For instance, Upender and Vardhini, 2020 developed a wheelchair system that can be controlled by hand gestures for individuals with disabilities. They suggested that further enhancements could include controlling the wheelchair with other body gestures, including eye gaze or leg or head movement, to improve versatility. The system also features a switch to toggle between touchpad and accelerometer controls, which increases its efficiency while reducing cost and size. The proposed wheelchair can be used in various environments, including hospitals, elderly care homes, airports, etc.

In 2021, Baltazar *et al.* (2021) proposed the Connected Driverless Wheelchair (CDW), providing on-demand mobility for hospital patients. The system integrates with the hospital's information management system and infrastructure to effectively transport patients, and avoid obstacles using sensors. Powered by two 12V batteries, it employs LiDAR sensors and an Arduino Nano within the joystick for navigation, promising to enhance patient transportation efficiency in hospitals.

Al Shabibi and Kesavan (2021) developed a smart wheelchair using Arduino and IoT technology to aid individuals with disabilities in their daily activities. The system, powered by Arduino Nano and ESP-12e module for Wi-Fi access, incorporates features such as fall detection with voice message notification, obstacle detection with a buzzer and LED indicators, and wheelchair control via joystick. It offers two modes of operation: automatic, where users command movement verbally, and manual, using a joystick. This system offers several benefits to those in need of smart wheelchair features. In addition, numerous prior systems, including those referenced as (Lakshmi et al., 2022; Khan et al., 2023; Gowri et al., 2023), have employed voice recognition in their designs. Lakshmi *et al.* (2022) introduced an Intelligent Wheelchair (IWC) governed by a real-time operating system (RTOS). Utilizing Google's voice assistance, users can issue commands for direction control, such as left, right, forward, and backward. The system incorporates touch screen navigation, obstacle avoidance, and fall detection, employing ultrasonic sensors for obstacle detection and a buzzer for fall detection.

In 2023, an IoT sensor-equipped voice-navigated wheelchair was developed by Khan *et al.,* 2023 to aid patients with physical limitations to navigate in a smart healthcare center. The wheelchair operates exclusively on voice commands from the user, allowing for autonomous navigation throughout the surroundings. Patients are located indoors or outdoors through the utilization of GPS technology on their mobile or tablet devices. Moreover, the use of IoT guarantees continuous connectivity to the healthcare center's network, enabling the wheelchair to receive updates and new functionalities. In addition, another voice-activated wheelchair has been proposed by (Gowri *et al.,* 2023). This system responds to user's voice commands to move in different directions, such as right, left, forward, backward, and stop. Furthermore, it offers a hand gesture control feature using patient's hand gloves, enabling patients who face difficulties with voice commands to navigate the wheelchair. The system also incorporates accelerometer and gyro sensors for fall detection, which are mounted on patient's hand or wheelchair to detect movements.

In order to improve mobility, safety, and independence for individuals with physical or visual impairments, Pushpa et al. (2023) developed an intelligent wheelchair. The system incorporates advanced obstacle detection capabilities, reducing the probability of accidents. It integrates various sensors, including ultrasonic, IR, and laser, enabling precise obstacle detection, efficient navigation, and instant notifications in real-time. Moreover, the wheelchair is controlled through a mobile application, ensuring convenience and safety. Finally, a limited number of smart wheelchairs offer multi-functionality. Zhou *et al.* (2023) introduced a versatile wheelchair using IoT technology. This system caters to individuals with disabilities and the elderly. Through integrating various IoT technologies like GPS, IoT sensors, and the oneNET cloud platform, the wheelchair performs multiple tasks seamlessly. The results demonstrate that these intelligent wheelchairs excel in tasks, such as navigation, position tracking, monitoring, medical reminders, etc.

To summarize the technologies utilized navigation methods for the wheelchair, the table below presents a comparison between the reviewed studies and the proposed system in this study.

Table 1: Technologies and navigation methods in reviewed studies and the proposed system

No	Paper	Technologies Used	Navigation Method
1	Alkhali & Oleiwi, 2019	Arduino UNO Quad-Board SIM 808 Two DC motors L298N DC motor driver control Servo motors voice recognition module Batteries and Jumpers	Voice-activated
2	Upender & Vardhini, 2020	Arduino UNO	Hand gesture

		Ultrasonic Sensor LCD Display Joystick L293d DC motor driver control Two DC motors Remote control HT12D and HT12E Power supply	
3	Baltazar *et al*., 2021	LiDAR sensor Arduino Nano Two motor drivers L298N DC motor driver control Wheelchair construction components	Joystick
4	Al Shabibi & Kesavan, 2021	Ultrasonic sensor Arduino Nano and ESP-12e module Buzzer and LED Two 12V DC geared motors L298N DC motor driver control 4x3.7V 18650 lithium batteries Wheelchair construction components	Voice-activated Joystick
5	Lakshmi *et al*., 2022	Ultrasonic sensor Arduino Nano Buzzer Two tier motors L293D DC motor driver control Node MCU RTOS framework and Google's voice assistance Wheelchair construction components	Voice-activated
6	Khan *et al*., 2023	VENS-voice module GPS and IPS Two DC motors Wheelchair construction components	Voice-activated
7	Gowri *et al*., 2023	Accelerometer and gyro sensors Bluetooth module Arduino UNO LEDs DC motors Motor driver Lipo batteries Wheelchair construction components	Voice-activated Hand gesture using hand glove
8	Pushpa *et al*., 2023	Ultrasonic, IR, and Laser sensors Node MCU Two DC motors L298N DC motor driver control Power supply Wheelchair construction components	Mobile App
9	Zhou *et al*., 2023	ECG sensor Node MCU Arduino UNO KendryteK210 module ESP8266 Wi-Fi module DC motors TLP181 motor driver oneNet Platform Wheelchair construction components	Joystick Mobile application Computer remote control
10	**Proposed System**	**Ultrasonic and IR sensors** **Arduino UNO** **Four DC motors** **L298N DC motor driver control** **4x3.7V 18650 lithium batteries** **Wheelchair construction components**	**Automatic line followed navigation**

This study addresses gaps identified through an extensive survey on smart wheelchairs designed for hospital use, aiming to assist individuals with disabilities and the elderly. The findings presented herein compose the primary contribution of this study. First of all, according to results presented in the table above, prior studies have used several navigation methods, including voice-activated, joystick, hand gesture, mobile app, etc. These methods may have a problem while implementation in real-time. Voice-activated is a main method which has been used, but it provides several issues, such as patients or elderly who have a problem with voice cannot use it, and also this method cannot be used in a crowded area due to noisy problem. Joystick and hand gesture are also having a problem for these patients who have hand disabilities. Moreover, there may be patients who lack experience with mobile applications, making the use of a mobile application for wheelchair navigation challenging. These mentioned problems have been solved by automatic navigation using line followed technic as it has been applied in this study. In addition, navigating to the accurate location and the hospital's room using voice-activated or other methods will face a huge problem, such as patients will not know the name of the room or doctor, or they will not have skills to go to the right location. So, this problem has been solved using colored line to go to various locations, so patients can use a colored line to go to a right location.

Additionally, employing a temporary sensor alongside a primary sensor is essential. If the primary sensor fails or cannot collect data, the temporary sensor will ensure continuous data acquisition. This technique was utilized during the implementation of the line-following system in this study. Using IoT is a great technic to use while implementing a smart wheelchair as almost all the prior studies have been used, but since the suggested system is proposed for the KRI, in KRI, we do not have a data center in hospitals so implementing IoT is challenging and therefore, we do not implement the IoT. However, to maintain and improve the proposed system, there is a plan to implement it and connect the system to the data center for each hospital.

3. METHODOLOGY

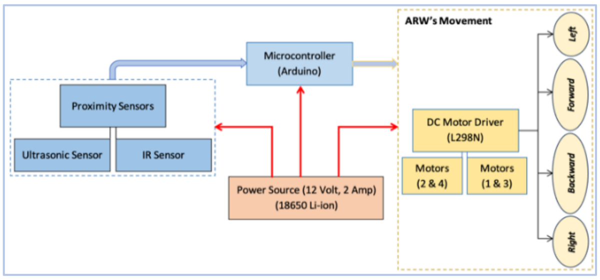

Figure 1: ARW's Block Diagram

The above diagram illustrates the general block diagram of the proposed ARW, which utilizes sensors like ultrasonic and IR sensors to gather surrounding data. Ultrasonic sensors detect nearby objects, aiding in obstacle avoidance, while IR sensors collect ground line data crucial for developing ARW-line followers. Using both ultrasonic and IR sensors for obstacle detection and line following provides a robust, complementary approach to navigation. Ultrasonic sensors are ideal for detecting and measuring the distance to obstacles, functioning well in various lighting conditions and sensing objects regardless of color or material (Lakshmi et al., 2022; Pushpa et al., 2023; Upender & Vardhini, 2020). On the other hand, IR sensors excel in line-following tasks, accurately detecting the contrast between a line and its surrounding surface, offering quick, real-time feedback (Krishnamurthi et al., 2020). Pushpa et al. (2023) stated that together these sensors improve a system's ability to navigate complex environments like hospitals, by ensuring it can effectively avoid obstacles and follow designated paths.

Unlike previous studies, our ARW autonomously moves based on predefined lines without human interaction. The IR sensor consists of an IR LED emitting or detecting IR waves and an IR photodiode as a sensor (Krishnamurthi et al., 2020) (as presented in Figure 2). Changes in output voltage and resistance of the photodiode correspond to variations in received IR light intensity.

Four IR sensors positioned in front of the ARW ensure reliable detection. Collected data is then processed by Arduino Uno, enabling collision avoidance with ultrasonic sensor data and controlled movement based on IR sensor data.

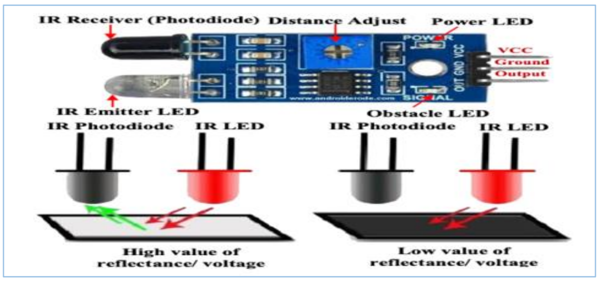

Figure 2: The IR sensor and its operations

Moreover, the power source comprises three Li-ion batteries, which supply power to the power distributor. Subsequently, the power distributor distributes power to the Arduino Uno, the H-bridge motor driver, and any sensors and devices in use, as shown in Figure 3.

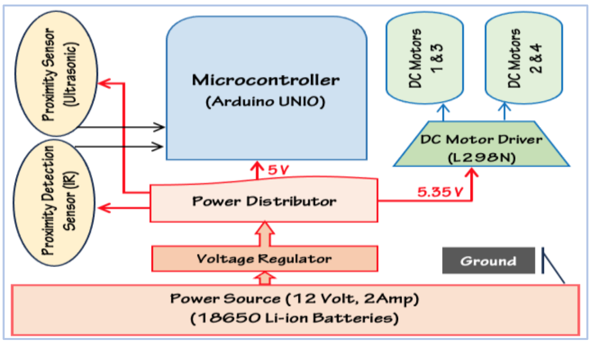

Figure 3: Connecting the components to the power source

There are several reasons to choose Li-ion batteries over other power sources like AA batteries, 9V batteries, or power banks. They offer higher energy density, longer lifespan, and consistent power output (Al Shabibi & Kesavan, 2021). Furthermore, Li-ion batteries are lightweight, rechargeable, and charge more quickly compared to power banks, making them ideal for portable devices. These features make Li-ion batteries more efficient and cost-effective for modern IoT applications, especially for this proposed system.

In order to evaluate the ARW, a predefined environment has been set up. The area is delineated with black lines, incorporating various navigational challenges, including forward and backward movements, right and left turns, and the presence of obstacles along the path. Figure 4 depicts potential navigation scenarios, where the ARW adjusts its direction based on the line using IR sensors when encountered left or right turns. Likewise, the ARW can detect obstacles on the line and maneuver accordingly by moving forward or backward as necessary. Although a black line was used in this study, it is noteworthy that alternative colors may be employed, allowing hospitals to customize their environments. For instance, blue lines might designate the operation section, black lines could indicate the X-Ray section, red lines might signify emergency areas, among other

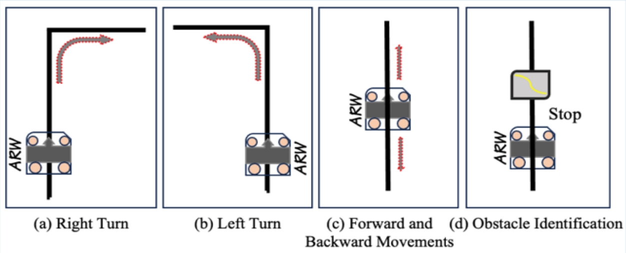

Figure 4: Possible Occurrence During Navigation

3.1 Software and Hardware Realization for Development of Autonomous Wheelchair

The proposed ARW is assembled using several hardware components as shown in Figure 5, each serving distinct roles in enabling its autonomous functionality and mobility.

Figure 5: The ARW's final version

At the core of the system is the Arduino Uno R3 ATmega328P microcontroller, functioning as the central processing unit responsible for executing programed instructions and controlling the wheelchair's operations. In addition, enhancing the wheelchair's perception of its surroundings are sophisticated sensing systems. An ultrasonic sensor provides accurate distance measurement, aiding in obstacle detection and ensuring safe navigation. Complementing this, four IR sensors contribute to the wheelchair's environmental awareness through detecting predefining lines and assisting in ARW's movements. To sustain prolonged operation, the ARW relies on a robust power unit consisting of three 18650 Li-ion batteries. This power source guarantees uninterrupted functionality, powering the various hardware components throughout the wheelchair's operation. Additionally, efficient motor control is achieved through the utilization of an H-bridge DC motor driver, specifically employing the L298N model. This critical component enables precise bi-directional control of the four DC motors, each responsible for driving one of the wheelchair's wheels. This feature is crucial for maintaining the ARW's smooth movement and maneuverability across various terrains. The mobility aspect of the ARW is further supported by the presence of four tires, which offer both traction and stability during movements. These attempts, along with the wheelchair's body serving as the structural framework for housing and integrating all hardware components, guarantee the stability and functionality of the overall system. Moreover, jumper wires play an important role as conduits for establishing electrical connections between components, enabling seamless communication and coordination within the ARW. Their pivotal role ensures the effective integration and operation of the various hardware components. Eventually, the assembly process encompasses several ancillary pieces essential for configuring and fine-tuning the ARW's functionality. These additional components contribute to the complexity of the system's design and operation, enhancing its overall performance. The precise arrangement and interconnection of these hardware components are outlined in Figure 6.

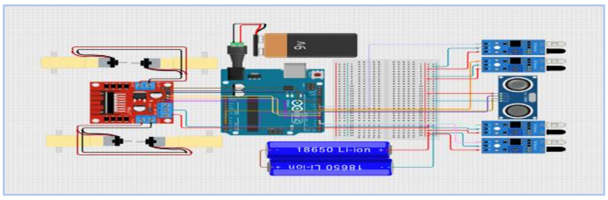

Figure 6: Circuit diagram of the ARW

The development of the ARW entails integration of the Arduino programing language with multiple supportive libraries. This programming language is an open-source, user-friendly programing language used to program Arduino boards, enabling the control and coordination of connected devices, as seen in the ARW. Furthermore, the Arduino IDE serves as the primary editor for writing the Arduino programing language. In this context, a program is referred to as a sketch and is usually stored with the "*.ino*" extension. The programing language used in the Arduino IDE is based on C++ and serves as the foundation for creating Arduino libraries (Dunbar, 2020). It compiles C++ code into assembly language, which is then used by the Atmel chips in Arduino boards to control and manage the boards and attached physical devices (Dunbar, 2020; Bell, 2021).

3.2 Prototype Model Development

The below figure illustrates the robotization of the ARW. In this, the Arduino Uno operates with two primary inputs: ultrasonic and IR sensors. The ultrasonic sensor serves to detect obstacles along the ARW's path, promptly transmitting data to the Arduino for action. Upon detection, the ARW can either stop its movements or navigate around the obstacle to continue its path.

What is more, four IR sensors positioned at the front of the ARW, two on each side, are employed to detect predefined lines guiding the ARW's movement. This arrangement enhances the precision of movement; if one IR sensor fails to detect the line, the others serve as backup, ensuring continuous line following. Upon collecting data from the IR sensors, the Arduino processes this information and communicates with the H-bridge, which controls the motors responsible for the ARW's movement in various directions, including forward, backward, left and right based on the activation or deactivation of the IR sensors.

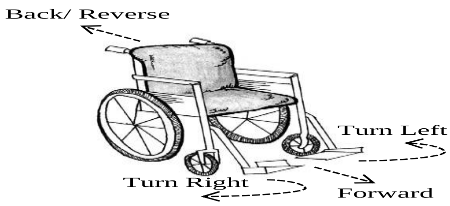

Figure 7: ARW Movement Paths

Figures 8a, 8b, and 8c depict flowchart illustrating the ARW's movements based on data gathered from two input sensors. In this representation, L1_distance and L2_distance denote detection distances for the first and second left IR sensors, respectively, while R1_distance and R2_distance represent detection distances for the first and second right IR sensors. Additionally, UL_distance signifies the distance between the ultrasonic sensor and the obstacle utilized for collision avoidance. Figure 8a illustrates the process of obtaining data from the ultrasonic sensor. Based on this data, it determines the presence of an object to facilitate obstacle avoidance.

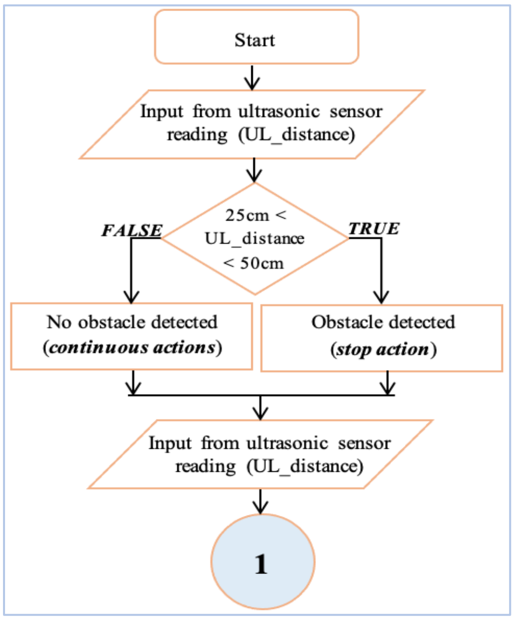

Figure 8a: Flowchart of ultrasonic sensors data collection

Additionally, Figure 8b depicts the data acquisition process from the IR sensors, enabling the ARW to manage and control movements based on the collected data.

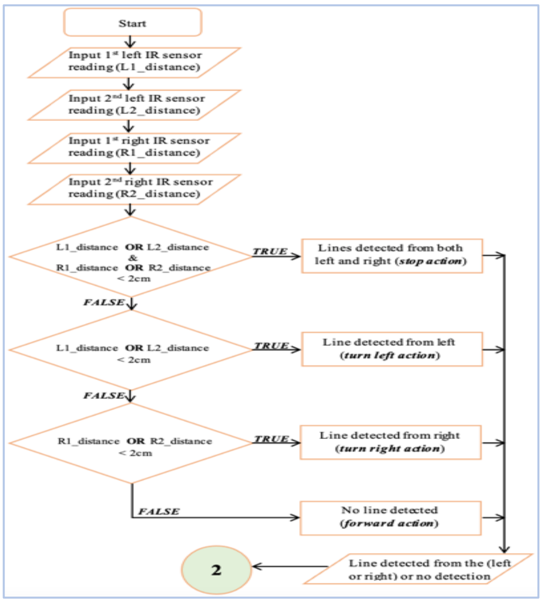

Figure 8b: Flowchart of IR sensors data collection

Finally, using the data collected from both sensors, the ARW can move in various directions or stop when obstacles are detected, as shown in Figure 8c.

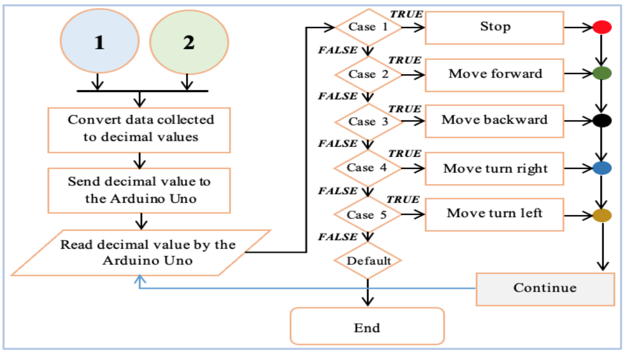

Figure 8c: Flowchart of the ARW's movements

4. RESULTS AND DISCUSSION

This proposed ARW is tested with all its features, including IR sensor control, line follower navigation, temporary sensor usage as a backup for the main sensor, and obstacle avoidance using an ultrasonic sensor. All these features deliver accurate output and an efficient framework for the patient, with low power consumption and no fuel wastage. This represents the complete implementation of the proposed hardware system, and a prototype has been successfully designed and built. The figure below shows the ARW moving along a black line. In practical applications, hospitals can use different line colors to represent various services, ensuring patients follow the correct color to reach their intended destination.

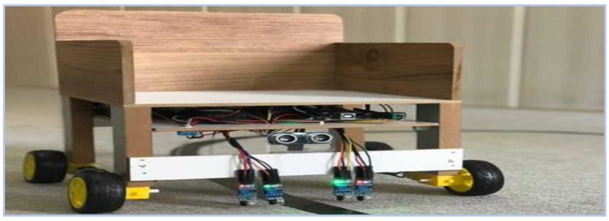

Figure 9: The ARW line while traveling using IR sensors.

In this study, a line follower that follows to any surface or visual line was developed using four IR sensor modules. Due to their reliable detection capabilities, four IR sensors, two on the left and two on the right, are being used in front of the ARW, as shown in Figure 5. Using two sensors on each side enhances accuracy compared to other systems, allowing for line detection even if one sensor fails. These sensors detect whether the line's color is reflected by sensing the light returned from the surface. While the reflecting surface can be of any color, only black lines on a non-reflective surface do not reflect light, as depicted in Figure 2. The sensors analyze the reflected light, and if there is no reflection, the IR sensor outputs a low or no signal. The Arduino then uses these high and low output values to control the ARW's movements, determining when to move, turn (left or right), or stop.

Moreover, the line follower approach enables automatic control and direction changes, a method not previously employed. This innovation can reduce congestion in hospitals during emergencies, as it eliminates the need for hospital staff to assist with patient movement. It is also faster and more accurate than manual approach, which can suffer from staff unavailability or increased crowding. Unlike voice-controlled method, which has been widely studied but can be ineffective in noisy environments or for patients with voice issues, the line follower approach proves to be the best solution for navigating wheelchairs in hospitals.

In comparison with recent studies, as previously discussed, the proposed system addresses the challenges encountered when navigating the ARW. For instance, four IR sensors were employed for automatic movements, which enhances reliability and accuracy compared to using just two sensors on each side. Additionally, our use of line followers for automated ARW navigation distinguishes our approach from previous methods, such as manual control, voice-controlled, or joystick navigation, which were less dependable and precise due to the aforementioned concerns. As a result, our approach can be considered more reliable and accurate compared to earlier methods.

In addition, the ultrasonic sensor positioned at the front of the ARW ensures obstacle avoidance. When the sensor detects an object ahead, it halts the ARW, enabling safe movements. To estimate the distance between the object and the ARW, the ultrasonic sensor uses the following calculation, determining whether there are any objects or obstacles in its path.

$$time = \frac{distance}{speed} \quad (1)$$

Suppose there is an object located 25 cm away from the ARW, and the speed of sound in air is 340 m/s or 0.034 cm/µs. This means it will take the sound wave 735 µs to travel that distance. The sensor then uses the following formula to determine the measured distance, which is divided by two because the sound wave travels to the object and back, covering twice the distance.

$$distance = \frac{speed*time}{2} \quad (2)$$

To determine the accuracy of the ultrasonic sensor, the ARW was tested in a real environment. Objects were placed at various distances to identify the optimal accuracy range and inform the ARW's construction code. Measurements were taken at distances of 25 cm, 50 cm, 75 cm, 100 cm, 125 cm, 150 cm, 175 cm, and 200 cm from the object. The average value for each interval was computed, and the accuracy and error of the measurements were estimated. Table 2 presents the collected data from the sensor, along with its corresponding accuracy and error rate.

Table 2: Real-time distance measurements from the ultrasonic sensor

No.	Actual Distance (cm)	Measured Distance (cm)	Accuracy (%)	Error (%)
1	25	24.99	99.96	0.04
2	50	49.96	99.92	0.08
3	75	74.68	99.57	0.43
4	100	98.56	98.56	1.44
5	125	122.92	98.34	1.66
6	150	146.82	97.88	2.12
7	175	169.4	96.8	3.2
8	200	192.6	96.3	3.7

Figure 10 illustrates the correlation between the actual and measured distances, showing the extent of deviation from the actual distance. The deformity is not severe, and the measured distance can be considered acceptable.

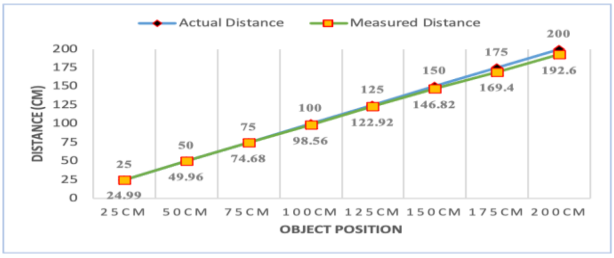

Figure 10: The relationship between the actual and measured distances

What is more, the accuracy and error rate along with the distance for ultrasonic sensor is depicted in Figure 11.

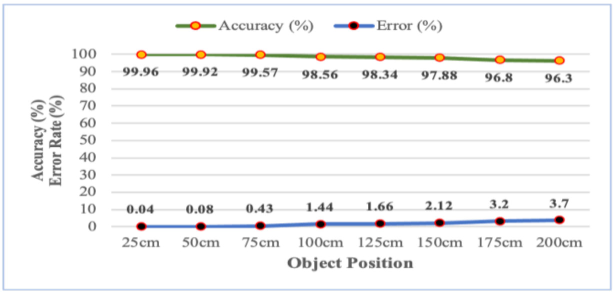

Figure 11: The accuracy and error rate of the ultrasonic sensor

The proposed system achieved the highest accuracies of 99.96% and 99.92% at actual distances of 25 cm and 50 cm, respectively, as demonstrated in Table 2. Therefore, the detection range used in the ARW spans from 25 cm to 50 cm, ensuring the highest level of accuracy based on the results. Additionally, efficiency decreases as distance increases. The highest error rate, approximately 3.7%, was observed at the actual distance of 200 cm. Overall, these results demonstrate that the proposed system outperforms current research in terms of accuracy. The findings were obtained through real-time testing, not under laboratory conditions, which further supports their reliability and accuracy compared to previous studies that relied on laboratory results. Moreover, it makes the proposed system highly suitable for hospitals, enhancing service delivery and reducing various emergency-related issues.

CONCLUSION AND FUTURE DIRECTIONS

In conclusion, given the rising need for efficient patient care and the specific challenges encountered in healthcare facilities, particularly with patient transportation, the development of the ARW represents a significant innovation. Traditional manual wheelchair operations in hospitals often results in inefficiencies and delays, especially affecting patients with limited mobility. Introducing ARWs equipped with advanced technologies like Arduino microcontroller, IR and ultrasonic sensors presents a promising solution to improve hospital efficiency and enhance patient care.

The proposed ARW operates autonomously in hospital environments by detecting obstacles and navigating predefined paths marked by colored lines. This reduces the need for manual assistance and mitigates risks associated with overcrowding and emergencies. The robust testing and evaluation of the ARW prototype have demonstrated outstanding performance, with accuracy rates reaching up to 99.96% at optimal distances. These results highlight its reliability and effectiveness in enhancing hospital operations. In addition, the total cost of implementing the proposed system is notably affordable, making it feasible for deployment in hospitals nationwide, particularly in the KRI. All in all, the development and deployment of the ARWs represent a significant step forward in modernizing healthcare delivery systems. By leveraging autonomous technology, hospitals can not only meet current challenges but also anticipate future needs, ultimately improving patient outcomes and enhancing the overall quality of healthcare services.

Due to its simple implementation, the concept of the system can be applied to a wide range of applications. This research shows significant potential for improving mobility for individuals with disabilities, thereby enhancing their independence and quality of life. Moreover, there is potential to integrate several other features to further enhance the quality of the system. Therefore, the future direction for the proposed system involves implementing IoT technology, eliminating the need for colored lines to designate various hospital services. By storing patient information in the cloud and employing facial or fingerprint recognition, the ARW can directly access and retrieve the patient's stored data from the cloud. This capability will enable the ARW to autonomously transport patients to the appropriate hospital services required for treatment. In addition, future research on the proposed system could focus on integrating advanced sensors and navigation algorithms, as well as incorporating machine learning to refine navigation capabilities. These improvements would make the system more adaptable and intelligent, further enhancing user experience and expanding the potential applications of autonomous wheelchair technology.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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