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Quadriplegic patient assistive system for requirement sharing and home appliance control using 3-axis accelerometer with IoT

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Abstract
This research article aims to develop a device that can help paraplegic patients who can only move their heads. Previously, head movement techniques were used to control wheelchair movements. The proposed device uses head movements to control appliances (lights, fans, etc.) and indicates the patient's different needs (water, food, etc.). In this system, a 3-axis accelerometer detects the movement of the paralyzed patient's head and sends it to a microcontroller. The microcontroller converts this signal and sends this to the second microcontroller via the Bluetooth module. The converted signal passes through a dot-matrix display that displays an image of each requirement. At the same time, the caretaker will be notified by a buzzer. In addition, the patient can control the appliances without outside help. In testing, the system shows superior accuracy when controlling appliances compared to LCD displays for special requirements. In the test run, the prototype shows the layout of head movement and detection of special needs.

Keywords Quadriplegic, 3-axis accelerometer, Bluetooth module.

Paper type Research paper

1. Introduction

According to medicine, paralysis is a lack of muscle characteristics in some elements of the framework. Any part of the frame can be randomly paralyzed at any time. There are up to three known reasons for paralysis: stroke, and multiple sclerosis. Currently, paralysis cannot be cured at any cost. Nerve or spinal cord wires are associated with paralysis. People with paralysis often have some form of nerve damage. “Stroke is the leading cause of paralysis in the United States, and 30% of cases are found only in stroke. Spinal cord injury is the cause of about 23% of cases. Multiple sclerosis said the Christopher Reeve Foundation. Symptoms cause an estimated 17% of cases”. Usually, many people can read, write, listen, or do anything because their body is ready to connect with the mind. In general, the mind is the director of the body, and the mind guides the body at

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every moment. However, some people encounter obstacles because they are unable to maintain their bodies to interact, accept, and send messages and impulses from the brain. In other words, the brain is running but the body is stopped. Their daily life and activities become difficult by paralysis. This type of person can think but can't complete their thoughts.

In the 21st century, paralysis is attacking many people's life. When the spinal cord is damaged, a person is affected with complete paralysis of both the arms and legs then it is called quadriplegic. Quadriplegia is also known as four limb paralysis. This type of patient cannot move their body totally without the help of other people. However, quadriplegic people only move their heads. Therefore, the purpose of this project is to develop devices that help patients use appliances such as lights and fans or ask for help by indicating pre-stored images with dot matrix display, through a predefined number of head motions.

Wheelchairs controlled by the head movement have already been invented. However, if the patient needs or has difficulty, or wants to convey certain commands to the caretaker or help, the commands are the patient's head movements and dot-matrix via a 3-axis accelerometer. It is transmitted via the LED display. Here, a 3-axis accelerometer is used to detect head movements, and based on head movements, quadriplegic people can share their needs with others. Therefore, patients and caregivers can easily interact.

Consequently, the first target of this project is to ready a helping machine that can assist the paralyzed patient. 24 hours assistance is needed for a paralyzed patient. But for now, it's not easy for everyone to be ready to help. In situations where the patient is alone in the room, you can use this device by moving your head and asking for help. The recent task is only for the inspiration that patients can easily communicate with others. If this process is implemented for the impaired person will surely help and the condition of paralyzed patient's life will be easier.

2. Literature review

Many systems have been proposed for patients with paraplegia caused by head movements. Among them some papers are presented in this section.

Goyal and Saini (2013) used a 3-axis accelerometer is to detect head movements and control two DC motors to control the wheelchair based on head movements.

Udayashankar, Kowshik, Chandramouli, and Prashanth (2012) have proposed a method that could help paralyzed patients control home appliances with a predefined number of blinks.

Mathew, Sreeshma, Jaison, Pradeep, and Jabarani (2019) proposed a novel idea by controlling the mouse cursor of a computer with the movement of the eyes, it controls home appliances for the disabled who can only move their eyes. The method proposed here uses eye-tracking to detect eye movements. This continues according to a simple circuit. This system is very helpful in solving HMI problems for people with disabilities.

Sourab, Chakravarthy and D'Souza (2014) proposed a project consisting of two systems, a patient-side system, and a notification or warning system depending on the patient's position, whether sitting or sleeping, the camera Adjusted to face the patient, the patient is connected to the system. The camera for this purpose, we use an IR camera to record video in the dark. First, the camera uses the Viola Jones algorithm to detect faces and try to focus on the area of the eyes Recognize blinking. These processes include the basic requirements for blinking Recognition in image processing. The news If you select, it will be sent wirelessly to the alerting system. The display of the microcontroller When the message is displayed, the patient's caretaker sounds a buzzer.

Cincotti et al., (2008) implemented a system that gives the user. A communication interface tailored to the individual's remaining motor skills. Patient (n = 14) Person with severe motor impairment due to progressive neurodegenerative disease System prototype as part of a refurbishment program in a homely room. All users support regularly used control options (such as micro switches and head trackers). In addition, four subjects learned how to operate the system using non-invasive EEG-based BCI. This system is controlled by the spontaneous modulation of the subject's sensorimotor EEG rhythms on the scalp. This skill was acquired despite the subject's long loss of control over his limb's time.

Kanithan (2021) proposed an idea that describes neural signals in the brain. The message generated by the brain was captured by the brain detector. These messages are split into data packets, and these packet data are sent to the transmission channel. The HADO measurement section can capture EEG messages and use the MATLAB GUI platform to convert the data into signals. Then, the commands in the home segment make components such as fans and lights work. This system is used assuming the random blinking of the human brain and the eyes that control the on / off state of home appliances.

Nonetheless, there is currently no mechanism in place for detecting head movements, which could enable quadriplegic individuals to express their requirements to others or directly manage household devices. Supplementary tools simplify communication with others, making it convenient to interact with a quadriplegic patient. The implementation of such a system is highly

advantageous, as it eliminates the constant need for caregivers to be physically present beside paralyzed patients. Our primary objective revolves around creating tools that enable paralyzed patients to convey their needs through a predefined set of head gestures. The central focus of our work is the necessity for both healthcare providers and caregivers to share information and regulate medical equipment, as it offers simplicity and convenience.
Some previous works related to our work in different ways are given below Table 1.

Table 1
Comprises prior research that is connected or relevant to our current work.

Related papers name	Publication date and range	Description
Implementation of Communication Model for Paralyzed patient using Non-invasive technique	2, February 2017	This system implements a communication model for paralyzed patient to detect eye blinking through a camera by using non-invasive technique.
Arduino Based Assistance Model for Paralyzed Patients Using Blink Detection	6, June 2019	Developed a device for disabled to connect with others by "An Eye Writer"
Eye Controlled Home-Automation for Disables	2006-2008	Analysis eye movement for paralyzed to control home appliance by sensors.
Assistance for the paralyzed using eye blinking detection	IEEE,2012	Design a device to assist patient to control appliance by pre-defined eye blinking.
Home automation using Internet of Thing	IEEE,2016	Dey, Roy and Das (2016) introduced a concept outlining the creation of a home automation system that utilizes both smartphones and computers to remotely control household devices from any location globally.
Implementation of home automation using eye blink sensor	2014-2015	Champaty, Jose, Pal, and Thirugnanam (2014) .suggested the development of a real-time blink sensor designed to detect eye blinks.
An approach to control appliances using EOG signal for physically challenged persons	2018, 285-295	Medola, Dao, Caspall, and Sprigle (2013) proposed examining E0G signals from household appliances to assist paralyzed patients through eye movement analysis.

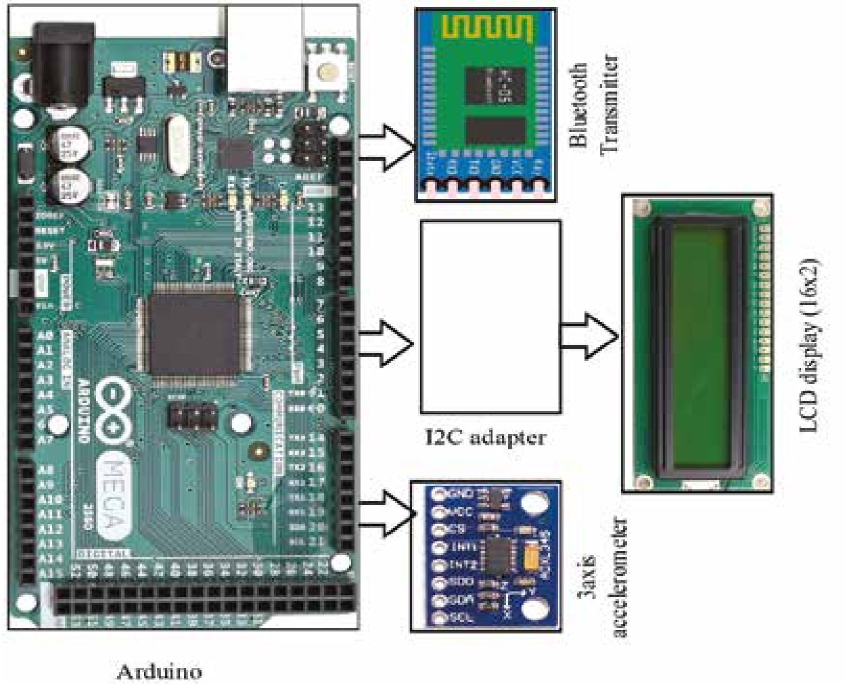
3. Development of the system

In this section, the authors have provided an overview of the system's block diagram, methodology, as well as the programming and algorithmic aspects of the system.

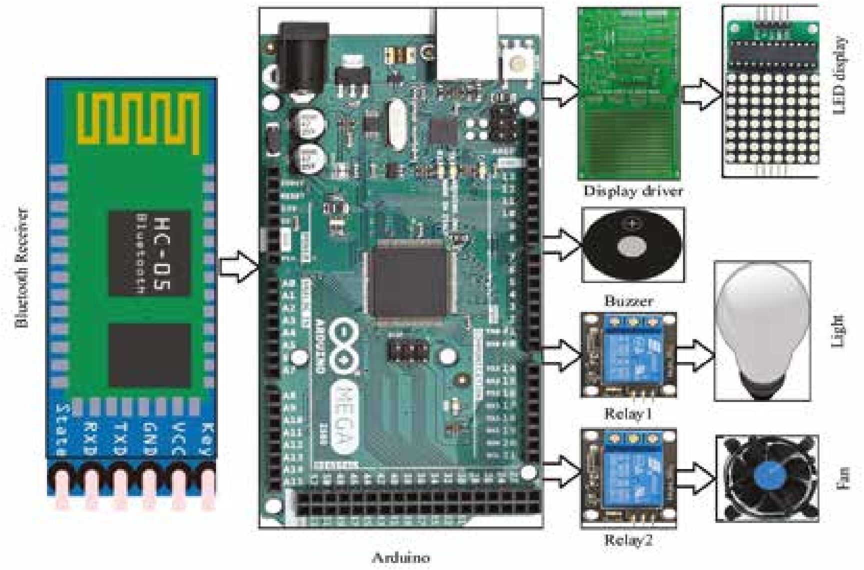
3.1. Block diagram of the system

The complete system is divided into two blocks as shown in figure 1. The blocks are named transmitter circuits and receiver circuits. The transmitter circuit is shown in figure 1(a). The purpose of the transmitter circuit is to detect head movements via a 3-axis accelerometer connected to the microcontroller. This sensor detects the movement of the patient's head and sends it to a microcontroller for conversion via a Bluetooth transmitter. On the transmitter side, there is an LCD display with an I2C adapter so that anyone can see what the patient wants to say in the message.

The Bluetooth transmitter sends data to the Bluetooth receiver connected to the microcontroller in the receiver circuit. The receiving circuit is shown in figure 1 (b). In the receiving circuit, the Bluetooth receiver sends the signal to the microcontroller. The microcontroller converts the signal into an LED dot-matrix display to image the patient's needs. After this was shown, the buzzer turned it into a tone. This device has a push button that allows the user to deactivate the system. With a predefined number of head movements, the patient can also have direct control over the appliances.



(a)



(b)

Figure 1
Block Diagram of the (a)Transmitter circuit and (b) Receiver circuit.

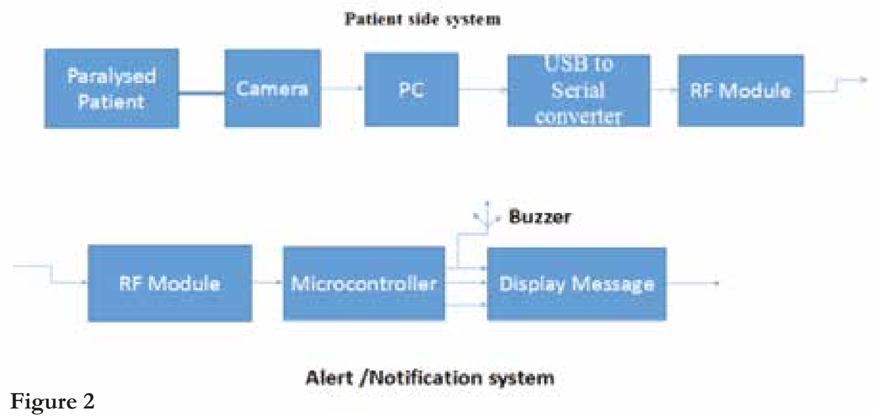


Figure 2
Block diagram of the system.

3.2. Methodology

The project consists of two main circuits: the transmitter circuit and the receiver circuit. It incorporates a 3-axis accelerometer sensor that interfaces with a microcontroller to detect a paralyzed patient's head movements. This system aims to increase the patient's engagement in activities by enabling communication through head motions.

The 3-axis accelerometer sensor detects the patient's head movements and transmits this data to the microcontroller via a Bluetooth module. The transmitter side utilizes an LCD to display messages corresponding to the detected head motion.

On the receiver side, the Bluetooth receiver receives the signal and converts it into sound using a buzzer. A LED dot matrix display is employed to show pre-stored images representing the patient's needs. When the patient selects a need by indicating an image, the buzzer generates a sound signal. The caregiver can then respond to the signal and assist the patient accordingly. Additionally, the device allows quadriplegic patients to control home appliances like lights and fans by executing predefined head motions.

Figures 2 and 3 display the comprehensive schematic of the project. The circuit was simulated using "Easy.EDA.std" and is divided into two main sections: the transmitter circuit and the receiver circuit.

In the transmitter circuit, there is a Bluetooth module connected to the microcontroller through pins 11, VCC (3.3 V), and GND. A 3-axis accelerometer is linked to the microcontroller via analog pins A4 and A5. The LCD display utilized in this system is a 16x2 LCD, with connections to the microcontroller through pins A5 or A4 for SCL and SDA. VCC and GND from the LCD are connected to the microcontroller's VCC (5V) and GND.

On the receiving side, a Bluetooth module is connected to the microcontroller via pin number 2, VCC (3.3 V), and GND. The LED dot-matrix display used in this setup is an 8x8 LED, with CLK, CS, and DIN connected to the microcontroller using pins 11, 10, and 12, respectively. Additionally, there's a push button and a buzzer connected to the microcontroller through pin numbers 6 and 7. Lastly, a drag relay is incorporated, with Relay1 and Relay2 connected to pins 9 and 8, respectively.

3.3. Programming and algorithm

In this setup, a 3-axis accelerometer sensor is utilized for detecting the head movements of paralyzed patients. This data is then sent to a microcontroller for processing, and from there, it's transmitted to another microcontroller through a Bluetooth module. To make this operation smooth, input/output pins are designated, and variables are initialized accordingly. The communication baud rate for the 3-axis accelerometer is configured at 96500 bps. The processed signal is subsequently displayed on a dot matrix display, visually indicating the specific requirements of the individual. Meanwhile, a buzzer is activated to alert the caregiver.

A 3-axis accelerometer is a device designed to measure acceleration along three spatial axes: the X-axis (forward and backward), the Y-axis (left and right), and the Z-axis (up and down). It gauges acceleration concerning a state of free fall, where only gravity is acting upon it, rendering 3D acceleration measurements in a default state of zero or weightlessness, despite the accelerometer's inherent mass. The ADXL345 accelerometer is interfaced with the I2C bus of the Atmega328P microcontroller, which is also linked to a 16x2 LCD display. The LCD display is utilized to convey messages indicating the needs of quadriplegic patients.

Two sets of transmitter and receiver circuits communicate wirelessly through two HC05 Bluetooth modules. For successful communication between these Bluetooth devices, one must serve as the master while the other functions as the slave. Once paired, the transmitter circuit's microcontroller reads 4 bytes of data from the 3-axis accelerometer (2 bytes for leftward movement and 2 bytes for rightward movement). The 4 least significant bits contain information about the Y-axis direction for rightward movement, whereas the 4 most significant bits contain data about the Y-axis direction for leftward movement. This 8-bit data is transmitted via Bluetooth to the receiver circuit. The first part is the transmitter flow chart shown in figure 4 and the second part in figure 5 is the receiver.

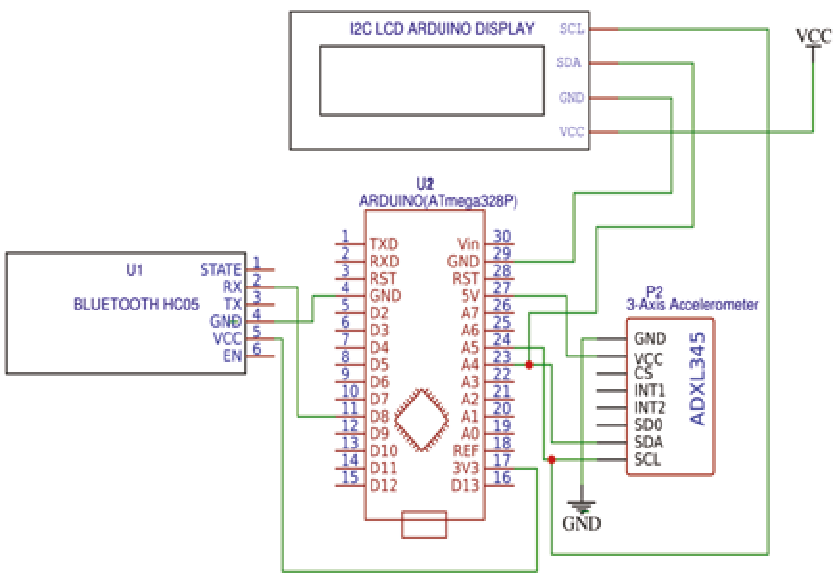


Figure 3
Transmitter circuit to detect head motion.

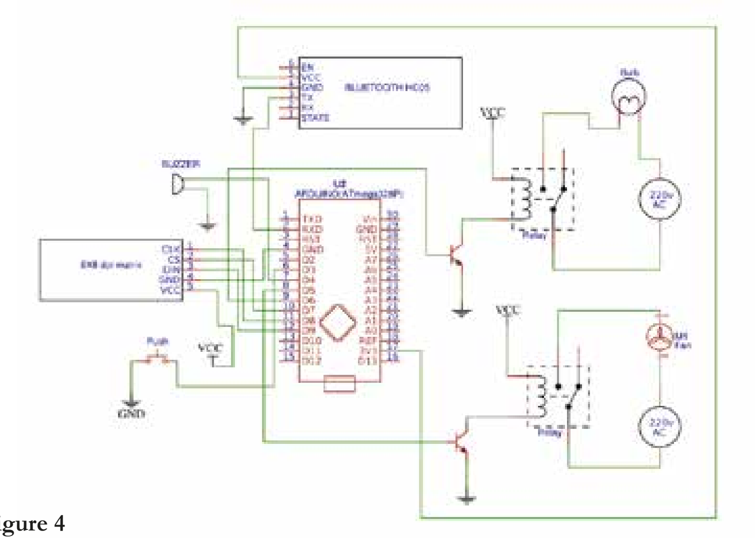


Figure 4
Receiver circuit to control home appliance and need share.

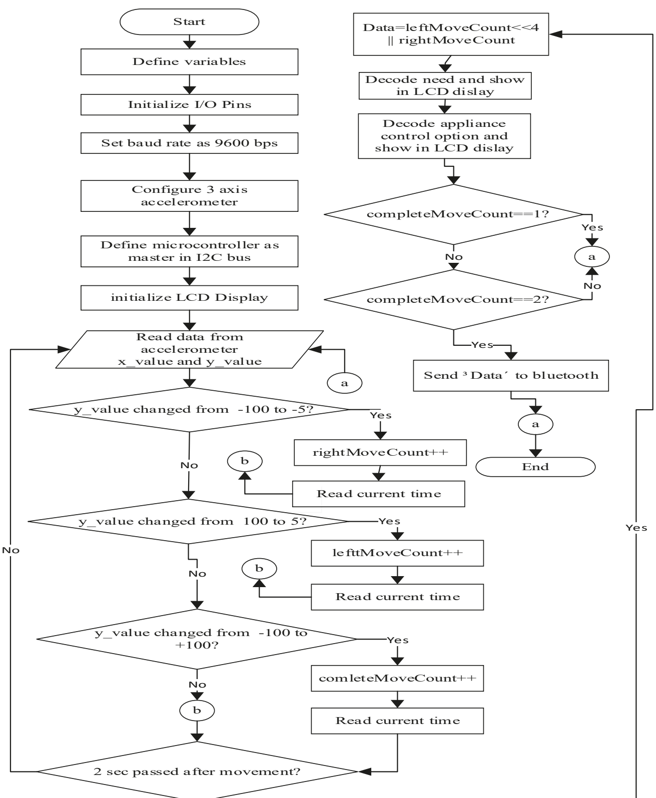


Figure 5
Flow chart of the program loaded in the microcontroller of transmitter circuit.

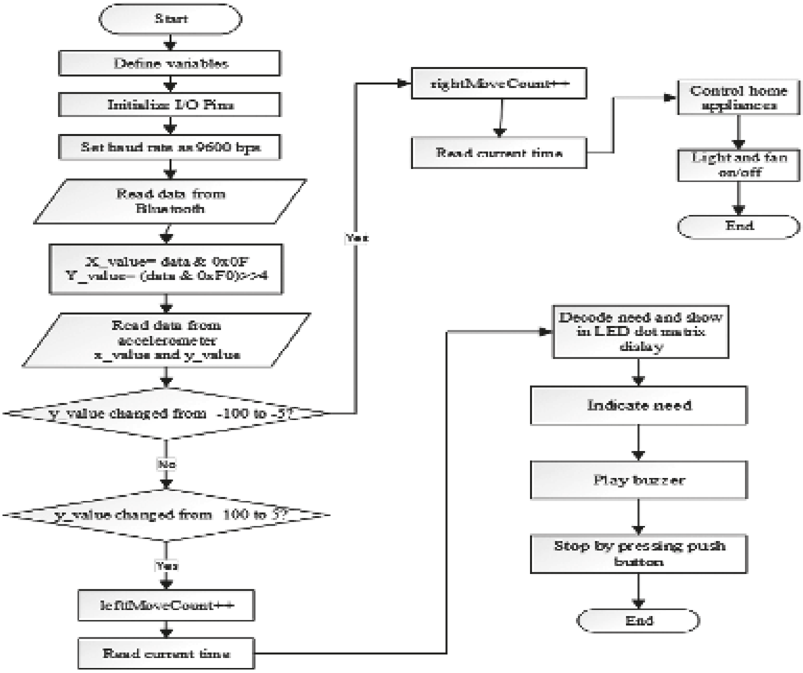


Figure 6
Flow chart of the program loaded in the microcontroller of receiver circuit.

4. Results and discussion

The entire system is illustrated in Figure 6, consisting of two main components referred to as the transmitter and receiver circuits. Figure 7 provides an overview of the devices utilized within the transmitter circuit. The primary function of the transmitter is to detect the movement of the patient's head, encode this data, and transmit it to a designated destination. Users can configure the movement parameters using a 3-axis accelerometer, and the resulting movement data, tailored for specific requirements and home appliance control, is displayed on a 16x2 LCD screen.

Figure 8(a) depicts the setup for detecting head motion using the 3-axis accelerometer. In Figures 8(b), 8(c), and 8(d), the Bluetooth module serves as the wireless transmitter responsible for conveying the accelerometer-measured data, which is then displayed on the 16x2 LCD screen for specific needs and home appliance control.

Figure 9 presents a comprehensive overview of the receiver circuit. The transmitter transmits the recorded head movement data to the receiver, where decisions are made regarding mobility, need sharing, home appliance control, and notifying family members or designated individuals about safety concerns.

Figure 10 showcases the home appliance control aspect, allowing patients to directly control fans and lights using their head movements. Specific messages corresponding to head motions are stored on an LCD display, enabling patients to turn lights on/off, activate/deactivate fans, or control both through head movements.

Figure 7
Complete overview of the system.

We selected specific parameter values to illustrate how the prototype functions. Figures 11, 12, 13, and 14 display the accelerometer sensor readings for head movements in different directions, with a focus on changes in the y-value.

In Figure 11, you can observe two full head movements where the y-value of the accelerometer shifts from 200 to 150. During this phase, data is transmitted based on these two complete head movements captured by the sensor. The horizontal axis represents the y-value of the accelerometer, while the bottom axis corresponds to the sample number. These head motions enable the patient to confirm and control home appliances and communicate their needs.

(a) An overview of the transmitter circuit.

90

Figure 8

Transmitting (b) left side view and (c) right side view of circuit representation.

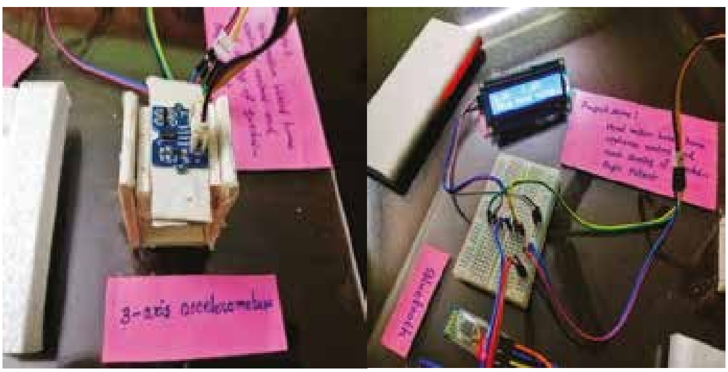


Figure 9

(a)   accelerometer for head motion detection (b) displaying home appliance control.

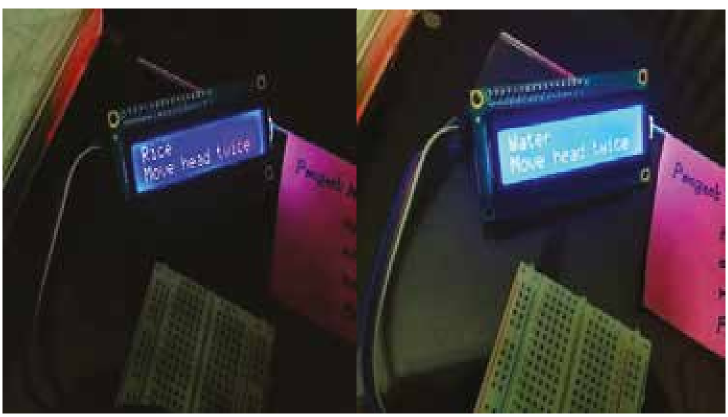


Figure 10

(c) (d) shows need sharing.

Figure 11
An overview of the receiver circuit.

(a) (b)

Figure 12
Overview of control home appliance.

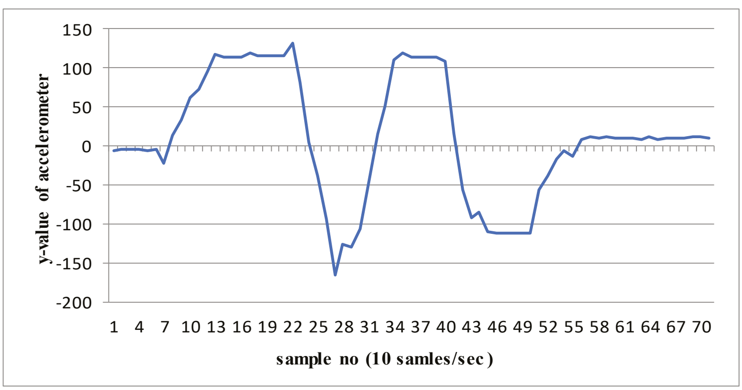


Figure 13
Variation of accelerometer value at complete two head movement.

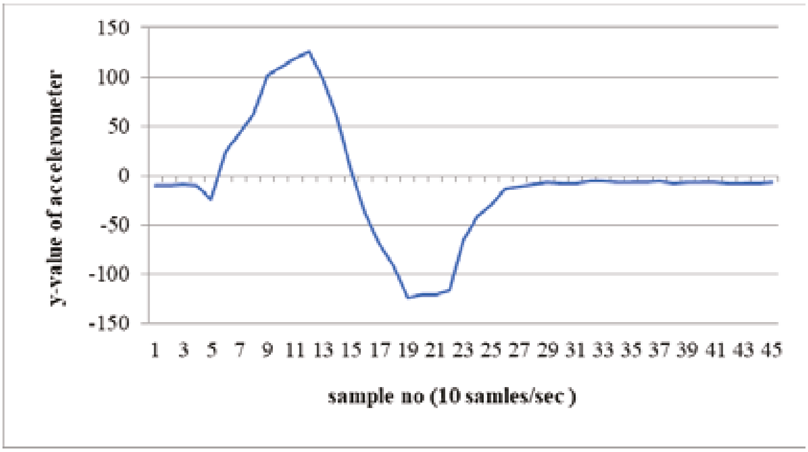
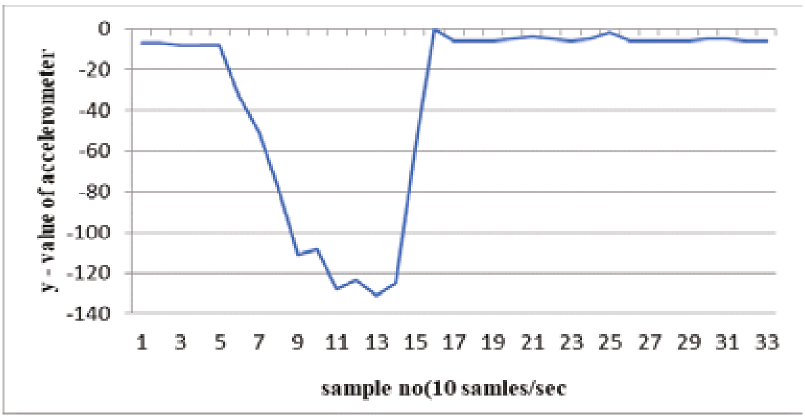
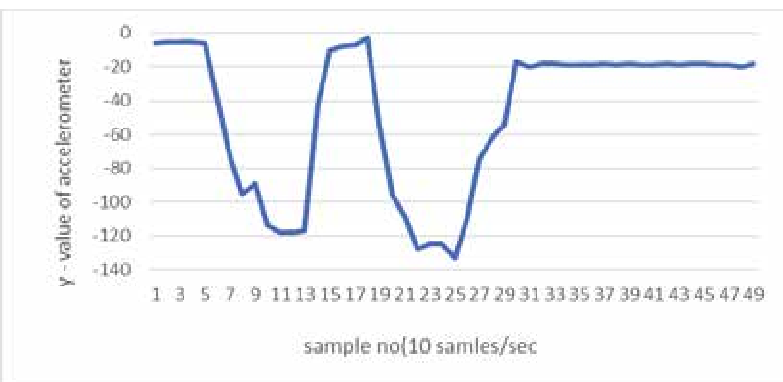


Figure 14

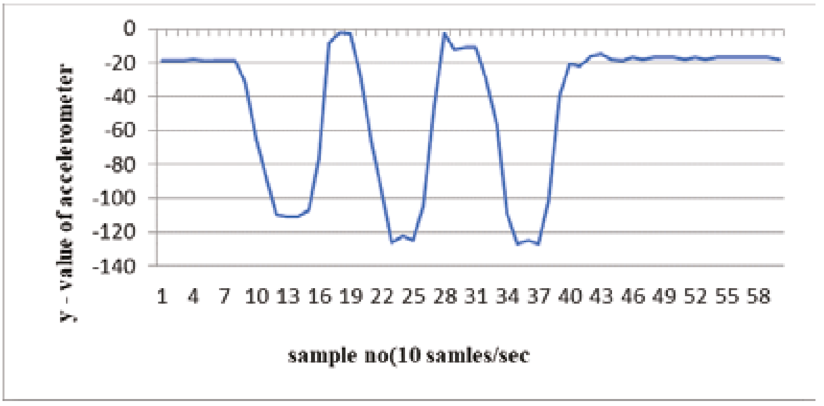
Variation of accelerometer value at complete one head movement.



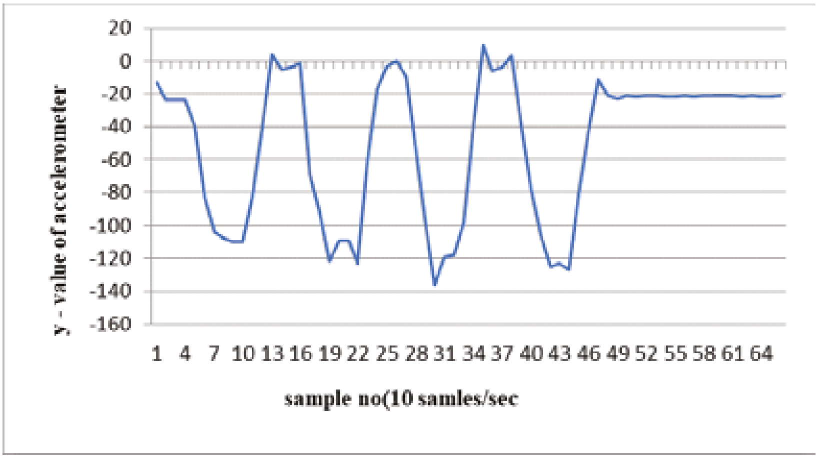
(a) Water indicates for one head movement in left direction.



(b) Rice indicates for two head movement in left direction.



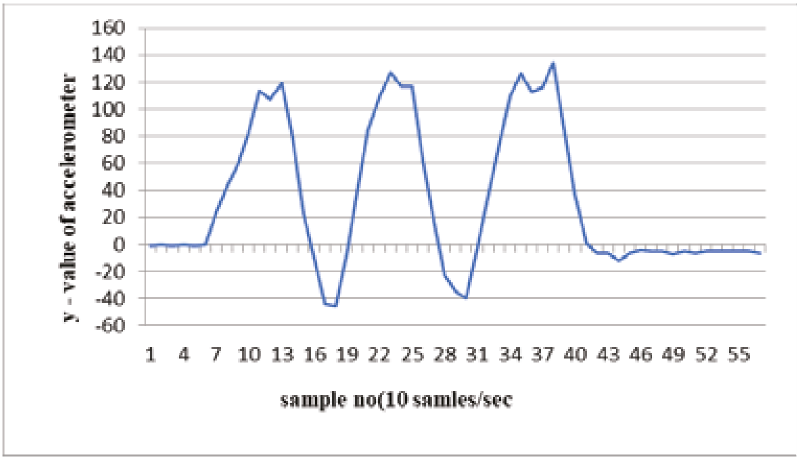
(c) Snacks indicate for three movement in left direction.



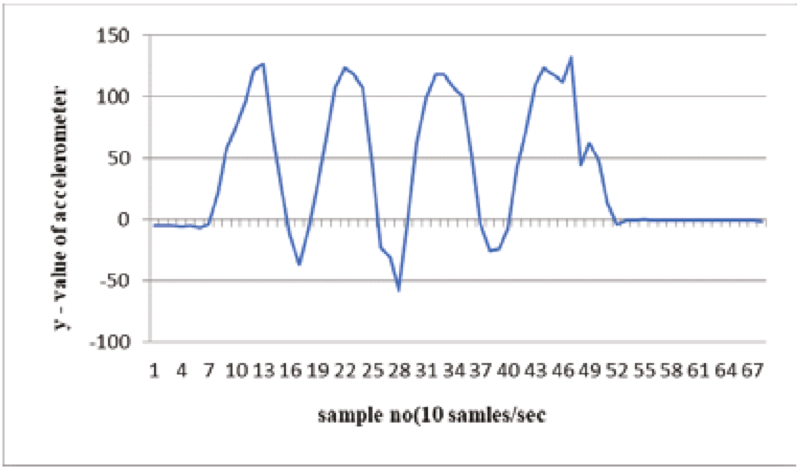
(d) Washroom indicate for four head movement in left direction.

Figure 15
Variation of accelerometer value during different head movement in left direction indicate of need sharing (a), (b), (c)and(d).

On the other hand, when the head is moved to the left, the y-value of the accelerometer increases from 140 to 20, each giving the same negative deviation without significantly changing the number of samples. These conditions are shown in figure 13. Changes in accelerometer values as you move the various heads to the left reveal images of water, rice, snacks, toilets, and mood on the LED matrix display.



(a) Light ON and fan OFF for three head motion in right direction.



(b) Light and fan OFF for four head motions in right direction

Variation of accelerometer value during different head motion in right direction indicate of home appliance control (a), (b). Similarly, when the head moves in the correct direction, the y-values of the accelerometer each provide the same amount of deflection without significantly changing the number of samples. The y-value of the accelerometer increases from 0 to 120. These conditions are shown in figure 14.

4.1. Detection of head motion by 3-axis Accelerometer Sensor

To detect the head movement, we have used a 3-axis accelerometer (ADXL345). A 3-axis accelerometer is a device that is designed to measure acceleration along three axes in space — the forward and back X-axis, the left and right Y-axis, and the up and down Z-axis. Since an accelerometer measures acceleration as related to a state of free fall, where no forces are acting on it except for gravity, 3D acceleration is considered at a default state of zero or in a weightless state, even though the accelerometer itself has mass.

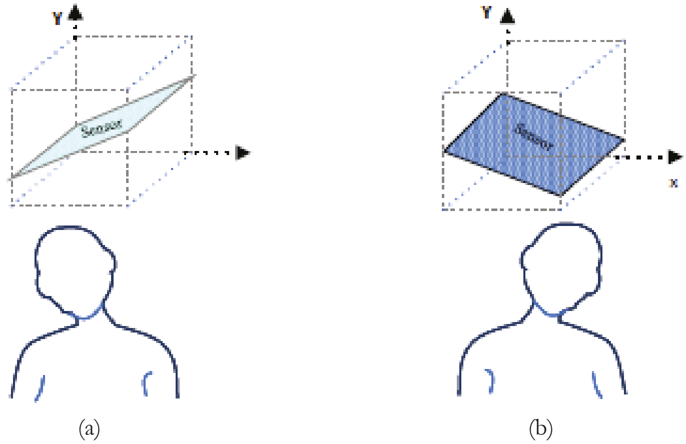


Figure 16
Sensor orientation when head tilted in the left and right direction.

The sensor is placed at the top of the head and in normal orientation of the head the sensor is parallel to earth surface. But when the head of the user tilted in left and right positions as shown in figure 15 the orientation of the accelerometer sensor is also change. This change of orientation varies the y-value of accelerometer sensor. The y-value of accelerometer sensor for different orientation are listed at Table 2

Table 2
y values for different head orientation.

Orientation of head	y-value
Normal	-10 to +10
Title in right direction	0 to 120
Title in left direction	-140 to -20

5. Conclusion

In summary, the rapidly advancing field of medical technology incorporates information technology to enhance communication among healthcare professionals. Various disabilities present different sets of symptoms, with quadriplegia being one of them, rendering patients unable to move any part of their body and leading to challenges in performing everyday tasks.

This project comprises two main segments: the transmitter circuit, responsible for detecting head movements, and the receiver circuit, designed to control and manage household appliances. The detection of head movements is achieved through a 3-axis accelerometer, and the recorded data is transmitted via Bluetooth, utilizing wireless communication. The Bluetooth module on the receiver end receives this data, initiating further processing actions, such as appliance control and the sharing of needs through images displayed on LED screens.

The primary aim of this project is to empower individuals with disabilities to freely communicate their requirements and independently manage their household devices. This solution is applicable to all quadriplegic individuals and is controlled through the movement of the user's head.

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