Innovative Mobility Assistance Device for Individuals with Disabilities

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Abstract:
Quadriplegics, people who cannot move any part of their body, may experience difficulties in their daily routines due to various factors such as age, stroke, arthritis, accidents, or birth defects. To assist these individuals, mobile assistance services have been introduced, including smart wheelchairs. These powered wheelchairs incorporate computers and sensors, allowing for navigation, detection, and autonomous movements. They can be controlled through a joystick and include safety features such as anti-tip bars, brake lever extensions, positional cushions, headrests, and seat belts. Smart wheelchairs are both affordable and rechargeable, providing a comfortable and convenient solution for individuals with physical disabilities.

Keywords: Head movements, Quadriplegia, Sensors, Pitch Values

1. Introduction

The spinal cord serves as a communication pathway between the brain and the rest of the body, and is safeguarded by the surrounding meninges and vertebrae. However, spinal cord injuries typically occur as a result of a sudden and severe impact to the spinal bones[1]. There are two categories of spinal cord injuries, namely complete spinal cord injury and incomplete spinal cord injury.

Individuals with complete spinal cord injury experience quadriplegia, which refers to paralysis of all four limbs and areas below the injury site. Conversely, those with incomplete spinal cord injury may retain some level of functionality as the nerves remain connected to the brain. Spinal cord injury patients are highly susceptible to respiratory complications and various illnesses such as pneumonia, cardiovascular disease, blood clots, and gastrointestinal problems[2]. These conditions can cause severe pain and discomfort for the affected individuals.

Annually, the number of people who suffer from spinal cord injuries ranges from 250,000 to 500,000. In India, the incidence of paralysis is increasing at a rate of approximately 50% per year, primarily affecting individuals between the ages of 30 and 50. According to the records, 80% of males suffer from spinal cord injury, with 53% experiencing partial or complete paralysis of their arms and legs, and 42% experiencing partial or complete paralysis of their legs[3]. The cost of treating such injuries falls within the range of Rs 23,771,200 to Rs 73,170,725, and there has been no improvement in life expectancy over the past three decades. To enable the movement of a smart wheelchair, control systems are applied to provide power based on certain signals, such as facial expressions or head movements[4]. The control system monitors the orientation and movement of the user's head to steer the wheelchair in the desired direction. This is achieved through the use of a gyroscope placed on the user's head, which detects the movement of their head.

The primary objective of this paper is to introduce a technologically advanced wheelchair that incorporates signal sensing capabilities, while also ensuring adequate safety measures and privacy protection.

Gyroscopic Control

The control of a gyroscope is used to track the position and angle of the user's head. This system is placed on top of the head and modifies the voltage passing through the wheelchair motors based on the user's head movements[5]. The mobility of the head is measured using a gyroscope, which is secured in a cap that also includes an RFID transmitter and receiver for real-time tracking. By moving their head to a specific side, the user can control the movement of the wheelchair as the corresponding motor is turned on to initiate a rotational movement.

Spinal Cord Injury And Its Types

The spinal cord comprises of tissues that extend from the base of the brain to the lower back and is protected by a membrane called vertebrae. It falls under the jurisdiction of the Central Nervous System (CNS) and serves as a conduit for transmitting information between the brain and other body parts in both directions[6].

The spinal cord serves two main control functions which involve transmitting signals from the brain to different parts of the body, and detecting reflexes.

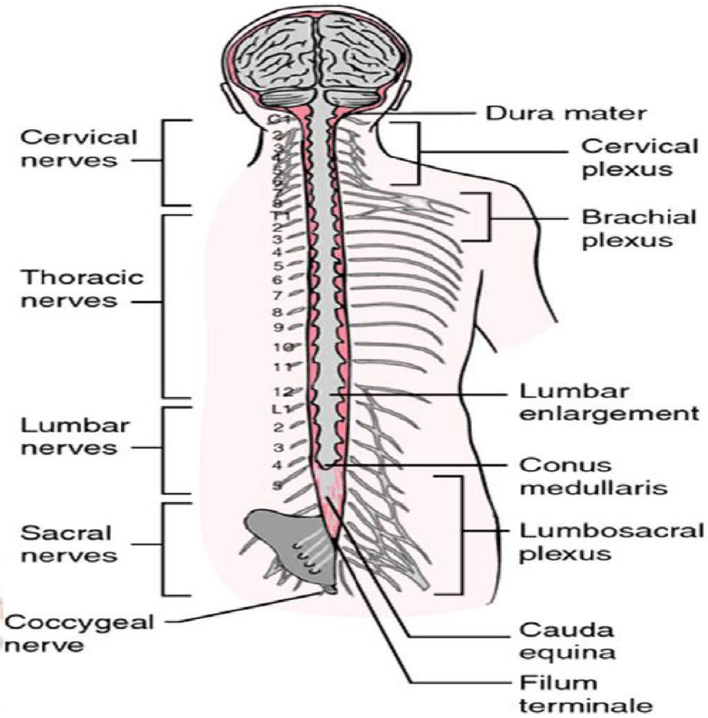

FIG 1: Spinal Cord Nerves

Spinal Cord Injury

Spinal Cord Injury is a neurological condition that severely affects individuals who suffer from it. The condition is caused by a damaging impact to the spinal cord and spine nerves, resulting in a significant impact on the sensory portion of the brain[7]. The damage caused by spinal cord injury can lead to permanent or temporary loss of function.

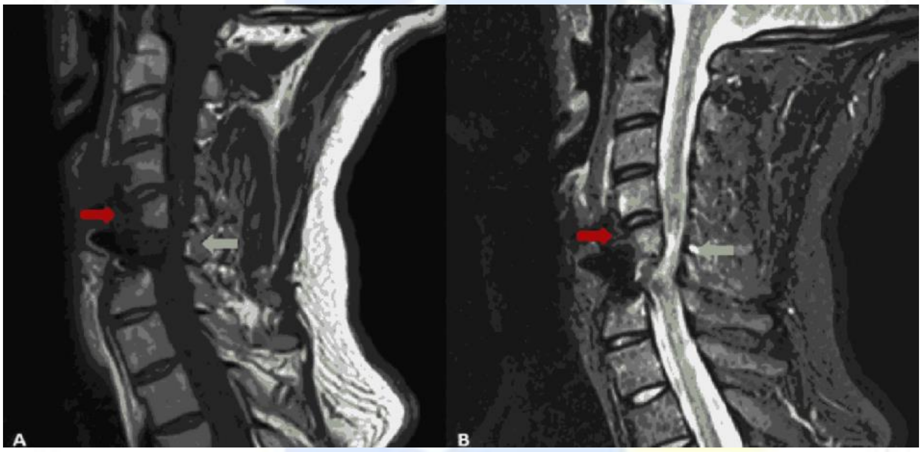

FIG 2: Spinal Cord Injuries

The majority of spinal cord injuries can be avoided, with the main causes being traffic accidents, gun violence, and sports-related incidents. Approximately 15% of these injuries occur in the thoracic and mid-thoracic/lumbar regions.

2. Existing System

The study reveals that individuals who suffer from paralysis can utilize tongue-controlled technology to access computer systems and operate a wheelchair via the Tongue Drive System. This system is beneficial for individuals with various disabilities as it enables them to communicate with their surroundings[8]. The tongue-controlled system is operated by the tongue's position, which triggers sensors attached to a headset that is linked to a circuit. By activating these sensors, the wheelchair motors can be controlled, allowing the user to move in all directions. The main aim was to create a comfortable and practical solution for individuals with disabilities, allowing them to use their tongues to control the wheelchair via magnets designed by the engineers. The magnetic field sensors, which are mounted on the headset placed outside of the mouth, detect the movement of the magnetic tracers.

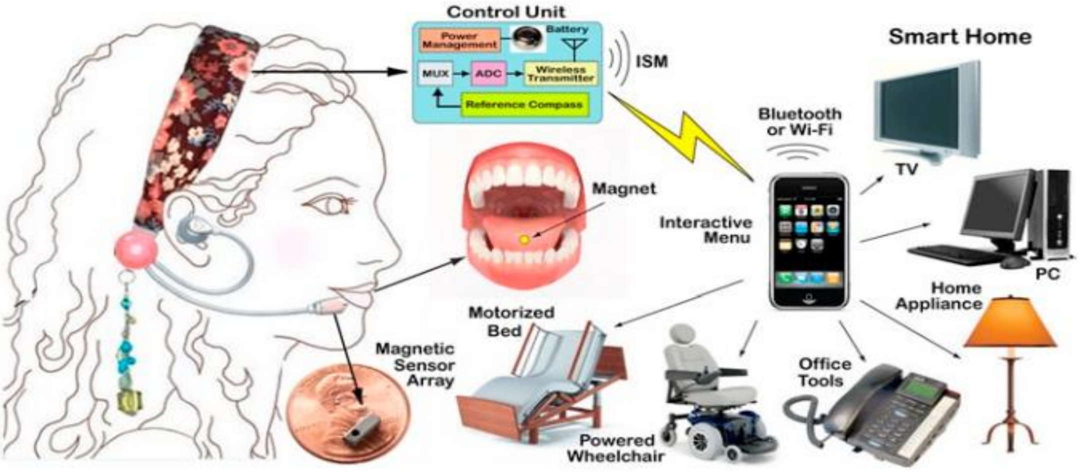

FIG 3:Overview of Tongue Driver System

Execution of Control Mechanisms

A wheelchair is a type of mobility aid with wheels that allows users to sit on it. The wheelchair can be operated manually, by turning the wheels using the hand, or through automated systems, such as the tongue drive system, where the movement of the wheelchair is controlled by a magnetic stud placed on the tongue. Wheelchairs are commonly used by individuals who have difficulty or are unable to walk due to illness, injury, or disability[9]. However, patients with generalized paralysis may require a specific type of wheelchair that can accommodate their needs and provide a more comfortable and convenient lifestyle. These specialized wheelchairs have small wheels attached to motors that can be activated based on the patient's requirements, allowing them to move around more easily.

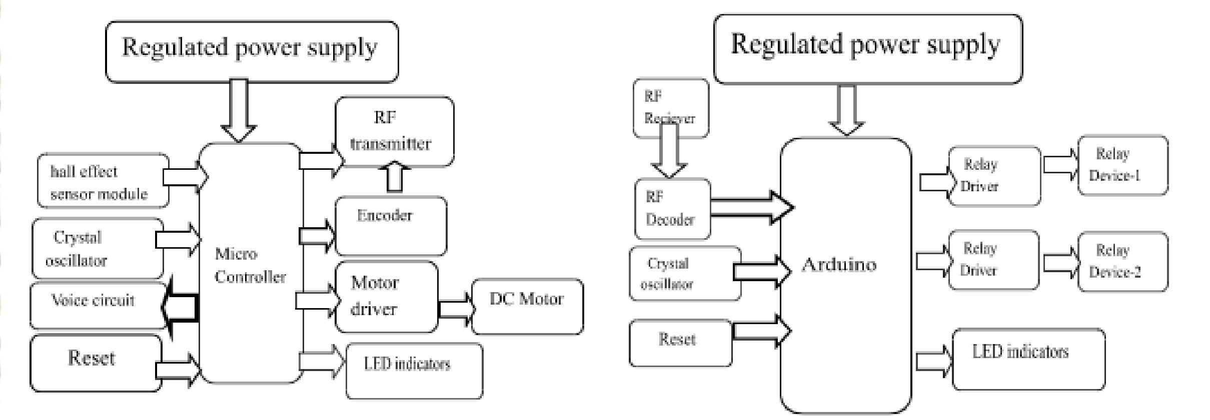

FIG 4: Block Diagram of Tongue Driver System Based on Magnetic Trace

Limitations of Existing System

- For instance, a more sensitive sensor that does not require a headset could be employed, while larger motors could facilitate faster and smoother movement.
- Alternatively, a simpler wireless circuit could be used, and the wheelchair could be programmed to move in more directions.
- An advanced steering system could replace the current tank-like method, and control switches could be worn by the patient to enable wireless control.
- Additionally, a system that allows the patient to give commands with their tongue to move the chair upwards could boost their confidence, and a set of sensors could be installed to prevent collisions with walls.

3. Proposed System

The purpose of this smart wheelchair paper is to enhance a traditional electric wheelchair by incorporating sensors to perceive the environment and a head movement interface to interpret commands. The development of intelligent wheelchairs is crucial for the future welfare society, as they can be seen as a partner rather than just a tool. The number of people with disabilities has significantly increased in the past century, and robotic wheelchairs can greatly assist in maneuvering and planning motion. The ability to move independently is essential for people of all ages, as it provides critical learning opportunities and promotes self-sufficiency. Those who lack independent mobility may face negative self-images and encounter obstacles when pursuing educational and vocational goals. While power wheelchairs may be suitable for many individuals with disabilities, up to 40% of the disabled population may struggle with standard power wheelchairs due to various physical or cognitive impairments. To address this issue, technologies originally developed for mobile robots have been utilized to create "smart wheelchairs."

Quadriplegia

Quadriplegia, also referred to as Tetraplegia, is a condition that results from an injury or illness causing partial or complete paralysis of all four limbs and the torso. Paraplegia, on the other hand, affects only the lower extremities and does not involve the arms. Both sensory and motor functions are typically affected, resulting in a loss of sensation and control. The paralysis can take on a flaccid or spastic form. Quadriplegia usually arises from damage to the spinal cord in the cervical spine, specifically between C1 and C7. The severity of the damage increases as the injury occurs higher up in the spine, and injuries at the uppermost levels can be fatal immediately.

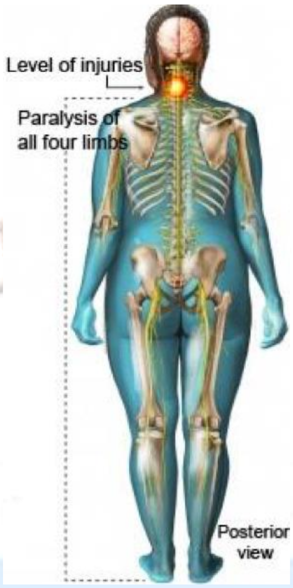

FIG 5: Quadriplegia Condition

4. Smart Wheelchair

A wheelchair is a chair that has wheels and is designed for individuals who have difficulty walking or are unable to walk due to an injury, illness or disability. There are different types of wheelchairs, including those that can be propelled manually by the person sitting in the chair or those that use motors for electric propulsion. Many wheelchairs have handles behind the seat, allowing others to push the chair.

A "smart wheelchair" is a type of wheelchair that incorporates sensors and a computer, either as additions to a standard power wheelchair base or as part of a mobile robot base with a seat attached. Designing a smart wheelchair for individuals with disabilities requires careful consideration of two important factors: the chair's adaptability to the user's specific needs and the fulfillment of safety requirements.

Objective and Need of Proposed System

The primary goal of this paper is to create a system that enables individuals to control a smart wheelchair using head movements, offering various levels of control for identifying obstacles and avoiding collisions, thus improving risk management. The paper introduces a novel wheelchair design model, which is specifically designed for physically disabled individuals to move around with ease. The wheelchair is equipped with a voice recognition system that makes it user-friendly and serves as an aid for individuals with physical disabilities. With obstacle detection and collision avoidance features, the wheelchair offers enhanced safety, including hollow detection to prevent potential danger in daily life. This design reduces dependency on caretakers and promotes self-reliance. The smart wheelchair can detect and avoid obstacles and reduces speed to ensure minimal obstacle clearance. It also slows down to approach closer to obstacles and objects.

The increasing prevalence of disability can be attributed to two distinct trends observed in data from the National Health Interview Survey (NHIS). One trend is the gradual rise, primarily caused by demographic shifts associated with an aging population. The other trend is a rapid increase due to health impairments and accidents. Conventional wheelchairs pose difficulties for many individuals, as a recent clinical survey revealed that 9%-10% of patients who received power wheelchair training found it extremely challenging or impossible to use it for their daily activities. Additionally, 40% of patients found the steering and maneuvering tasks difficult or impossible, particularly those suffering from motor deficits, disorientation, amnesia, or cognitive deficits, who depend on others to push them and feel powerless and out of control. Intelligent wheelchairs have the potential to compensate for these impairments and provide effective solutions to alleviate the impact of these limitations.

Block Diagram Of Proposed System

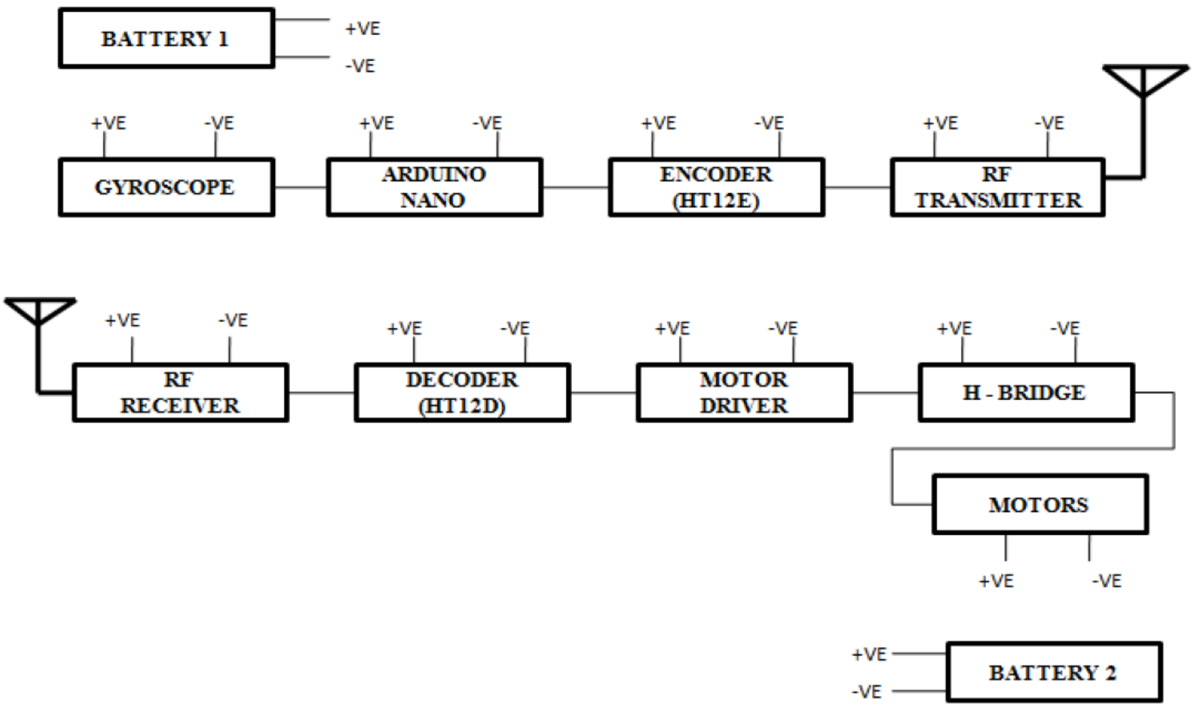

FIG 5: Block Diagram of Proposed System

The diagram depicts a power source that provides energy to the entire system, which can be divided into two sections: the transmitter side and the receiver side. The transmitter side comprises a Gyroscope sensor in the head cap worn by the user, which is connected to an Arduino Nano board. Additionally, the Encoder, also known as HT12E, is linked to the Arduino board to encode the data on head movements. On the other hand, the RF Receiver located on the receiver side receives signals from the transmitter, which is then decoded by the HT12D Decoder and sent to the driver circuit. The H-Bridge is then activated, and the motors are controlled by the information provided by the driver circuit, resulting in a head movement-based control system. The system primarily relies on three parameters: PITCH, ROLL, and YAW, which are calibrated using the Gyroscope sensor. The wheelchair's movement is then determined based on the set and calibrated values of these parameters.

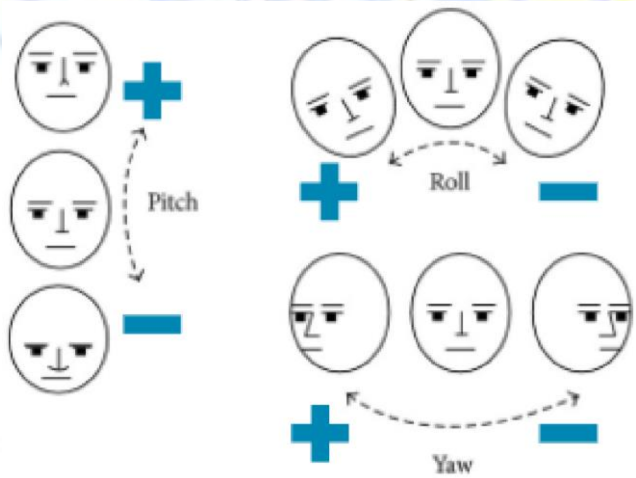

FIG 6 Pitch, Roll and Yaw Movements

Flowchart of RFID Control System based Wheelchair

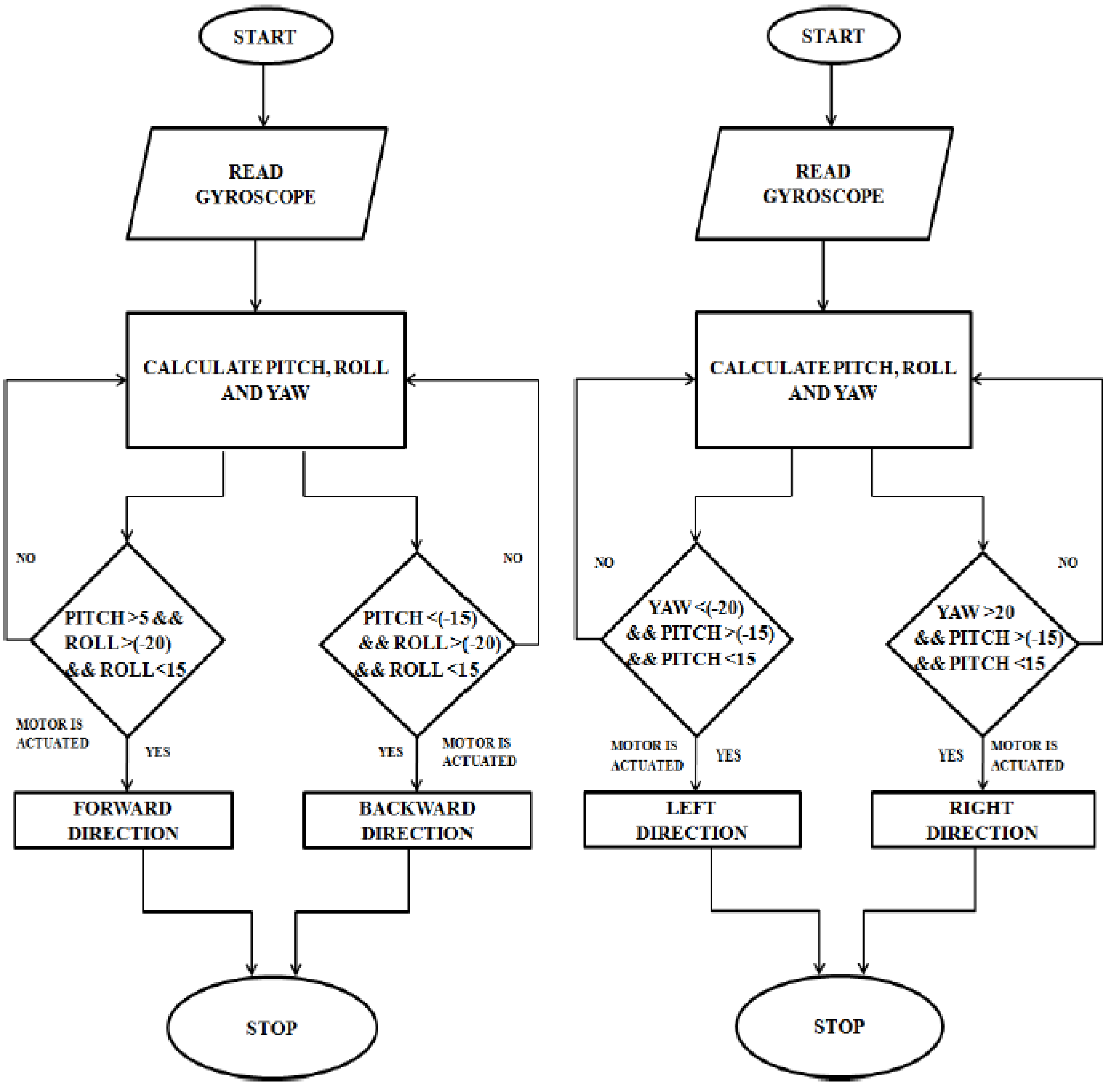

FIG 7: A) Flowchart for Forward & Backward Movement B) Flowchart for Left & Right Movement

Control Mechanism and Working of RFID Wheelchair

The functioning and control of the wheelchair rely heavily on the input values of Pitch, Roll, and Yaw. Initially, we set the Pitch condition to zero to enable the wheelchair to turn on or off. We determined that the optimal range for the average value of Pitch should be between -25 and +25 for the wheelchair to function correctly. To turn on the wheelchair, the value should be approximately +15, and to turn it off, it should be -15. Moving the person's head forward or backward twice within these range values will activate or deactivate the wheelchair.

To propel the wheelchair forward, the person should move their head slightly forward, which will increase the Pitch value from 0 to +20, causing the wheelchair to move forward. Conversely, to move the wheelchair backward, the person should move their head slightly backward, which will decrease the Pitch value from 0 to -20, resulting in the wheelchair moving in reverse.

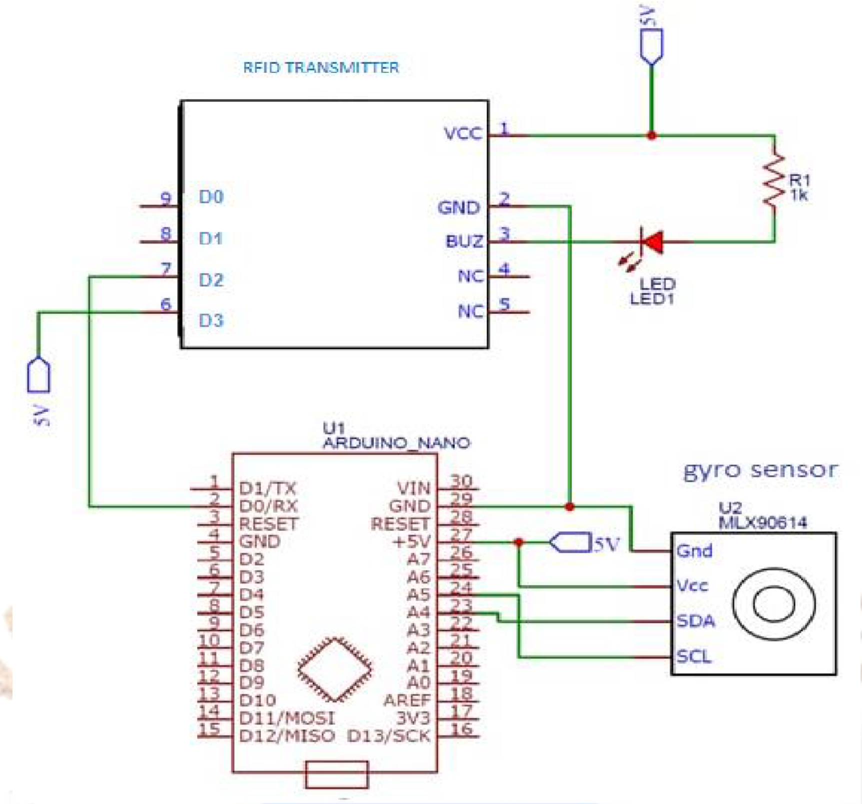

Fig 8: Circuit Diagram for Transmitter in the RFID based wheelchair

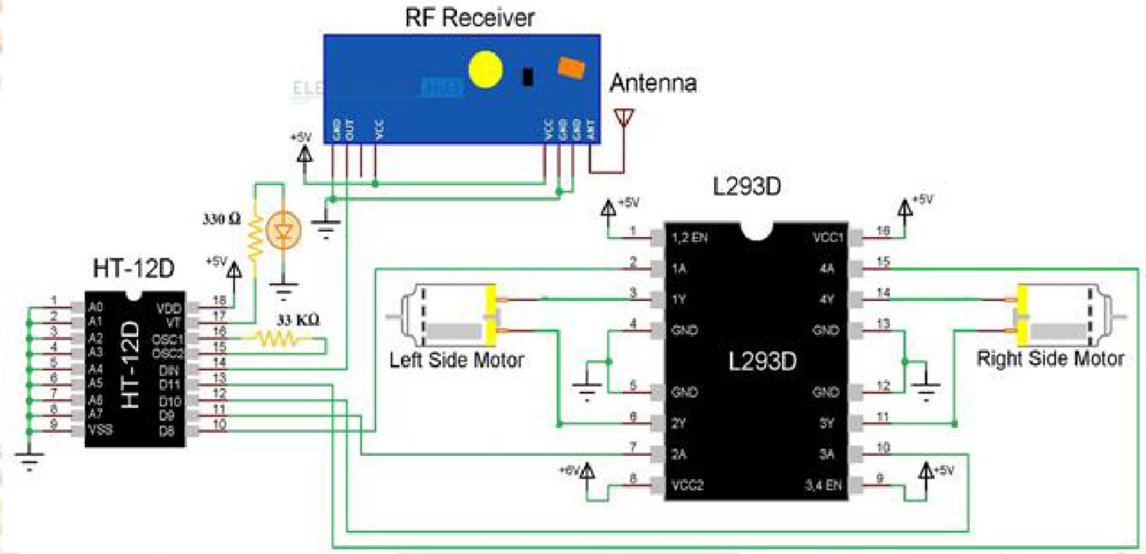

FIG 9: Circuit Diagram for Receiver in the RFID based Wheelchair

When commanding the wheelchair to move forward, achieving rotational or lateral movement directly is not possible. To achieve this, the Pitch must be reset to 0 before giving the command for left or right direction control. The Pitch values must be within -15 to +15 for rotational movements. Sideways movement of the wheelchair occurs when the person moves their head sideways, causing a corresponding change in the Pitch value. These conditions have been summarized as necessary for the movement of the wheelchair

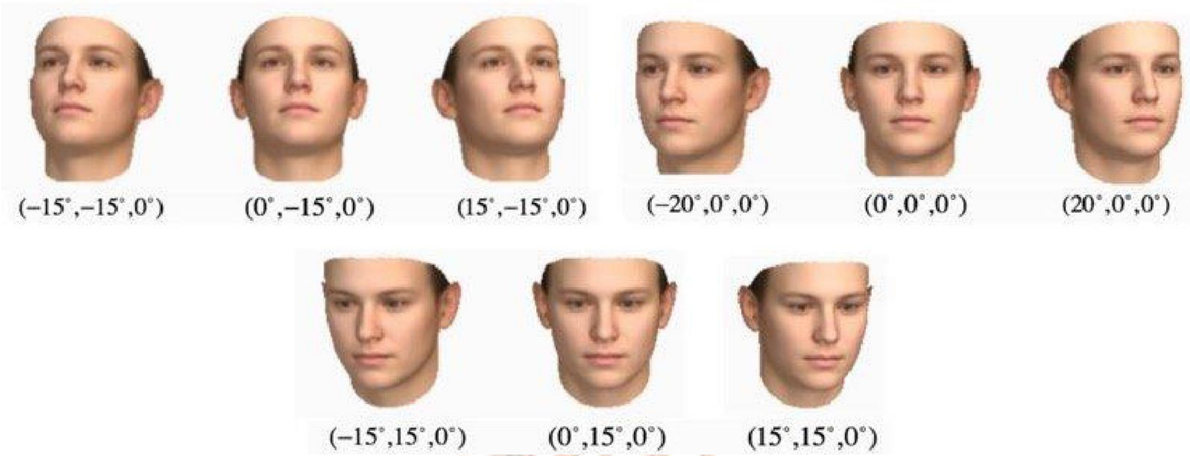

FIG 10: Head Movements and its Parameters

Table 1: Commands and Range of operation

DIRECTION	RANGE OF THE PARAMETERS
FORWARD	PITCH >5 && ROLL >(-20) && ROLL <15
BACKWARD	PITCH <(-15) && ROLL >(-20) && ROLL <15
LEFT	YAW <(-20) && PITCH >(-15) && PITCH <15
RIGHT	YAW >20 && PITCH >(-15) && PITCH <15
STOP	PITCH >(-15) && PITCH <15 && YAW <20 && YAW >(-20)

In order to control the direction and braking of a motor, an H-bridge can be employed, which consists of four switches labeled S1, S2, S3, and S4. By closing switches S1 and S4, a positive voltage is applied to the motor, causing it to rotate in one direction. To reverse the motor's direction, switches S1 and S4 are opened while switches S2 and S3 are closed, resulting in an inverted voltage being applied. The H-bridge motor driver circuit is commonly used to change the direction of the motor and to apply the brakes. To bring the motor to an abrupt halt, the terminals of the motor are shorted. Alternatively, the motor can be allowed to come to a stop on its own by detaching it from the circuit.

Results & Discussion

The wheelchair enables individuals with quadriplegia to move independently, eliminating the need for assistance from others and reducing the need for human labor. As a result, these patients can gain confidence and freedom in their movements. The wheelchair also addresses the main limitation of the Tongue Driven Wheelchair, which is sudden undesired movement during communication. The paper aims to empower individuals who are unable to walk or move by allowing them to go wherever they want, just like any other person. The ultimate goal is to promote a sense of normalcy and self-confidence among these individuals, thus contributing to a better world for everyone.

FIG 11: Head Gesture Controlled Wheelchair Based on RFID

5. Conclusion and Future Enhancement

This paper utilized RFID technology to wirelessly control a power wheelchair using head movements, with parameters such as Pitch, Roll, and Yaw calculated for accurate control. The use of RFID improved upon previous results achieved with Bluetooth technology, increasing ease of use. This paper could be further improved by implementing Image Processing techniques to enhance obstacle and person detection, improving the system's efficiency. Additionally, the authors highlight the benefits of reclining or tilt-in-space wheelchairs for individuals with postural deformities or pain, as well as the value of all-terrain wheelchairs for accessing a variety of terrains while maintaining stability

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