Smart Rehabilitation System for Quadriplegics

Nikhil Sawake, G Krishna Sumanth, Tushar Jagdale, Honey Gupta, Akshay Khatri

Abstract— **Quadriplegia is an injury to the spinal cord that results in the loss of sensory and motor receptors, leading to the loss of limb movements.**
Various assistive technologies that empower people with severe physical disabilities to achieve maximum independence at home and in the community were proposed. The currently existing technologies are based on eye and head movements, which may result in frequent undesired motions. A tongue driven system in which a small permanent magnet is attached to the tongue through piercing was also proposed.
This paper proposes a rehabilitation system as an advancement to the tongue driven system. It works on the principle of detecting the tongue's contact with the cheek, overcoming the drawback involved in the tongue driven system which requires a magnet to be pierced on the tongue which is practically undesirable. The rehabilitation system developed enables the disabled person to drive a powered wheel chair using tongue movements. It allows them to control the basic home appliances needed in their day to day lives. It also monitors their health and generates emergency calls and text messages in case the user is ill.

Index Terms—**Assistive Technology, Home Automation and Wheel chair, Quadriplegics, Tongue-Driven system**

I. INTRODUCTION

Quadriplegia is the paralysis of both the arms and legs. It is caused by the damage to the segments of the cervical spinal cord. According to a countrywide study on disability by the National Sample Survey Organization (NSSO) there are 8.9 million cases of locomotor disability in India around 17.5% of which are quadriplegics. While the needs of the people with paraplegia can be met with their functional limbs, it is difficult to achieve independence in case of quadriplegics.
Problems faced by the quadriplegics include:

- They cannot navigate independently.
- They cannot control basic home appliances.

Our work aims to provide solutions to above mentioned problems in cost effective and reliable manner enabling the quadriplegic person to achieve in-dependability to perform various day to day tasks. This is an attempt to provide a normal lifestyle to the disabled.

A. Technical Background

Currently existing systems for the quadriplegics primarily cater to their mobility needs. Some of them are based on eye movements [1], which may result in frequent undesired motions of the wheelchair, others involve navigation based on head movements [2] which may be very inconvenient in the long run, yet others are based on surface electromyography[3] and signals from the brain cells[4] which makes navigation more complex and unreliable. A tongue driven system in which a small permanent magnet is attached to the tongue through piercing was also proposed.[5][6][7].

These systems do not address other problems that quadriplegics face in their day to day lives.

This paper presents a novel rehabilitation system based on tongue movements. It enables the affected person to drive a powered wheel chair using tongue movements, thus navigation is more easy, reliable and effortless as compared to the existing systems. It continuously monitors their health, and generates emergency calls and text messages in case the user is ill or requires medication or any sort of help from the caregiver. It also allows them to control home appliances (like fans, lights, television, etc.) used in their day to day lives.

B. Proposed Solution

Our proposed solution is completely different from existing ones and provides complete independence to the person. Inspired by touch technology, our proposed solution works on the principle of capacitive touch. The movement of tongue enables the cheek to touch the copper plates which acts as an input to the capacitive touch sensor, resulting in an output which is transmitted wirelessly to a micro-controller, from which different tasks are controlled wirelessly in turn. These tasks include home-automation (switching lights and fans on and off), wheel chair navigation, control of television (power control, channel surfing, volume control) and automatic message or call sender through GSM module in case of emergency.

C. Organization of the Report

In this paper, first we propose the ideas to enhance tradition mobility or rehabilitation systems. In later section we present the hardware and software implementation of the system. Then we have mentioned observations and test results

II. PROPOSED SOLUTION

Our proposed solution is based on tongue driven system. A headset is mounted on person's head. The headset has two copper plates which act as sense electrodes. These touch plates act as input device to the system. With the help of right and left gesture, the user can navigate through all the modes of operation and perform all necessary tasks. Based on the touch input, the sensor IC gives high or low output which is then wirelessly transmitted to the main controller. Based on these inputs from touch sensors, microcontroller sends commands to various modules wirelessly. There are four modes of operation, viz. home automation, television, wheel chair mode, emergency and messages mode.

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Figure 1: Headgear Assembly
(The touch of the cheek is detected by the copper plate due to the movement of the tongue)

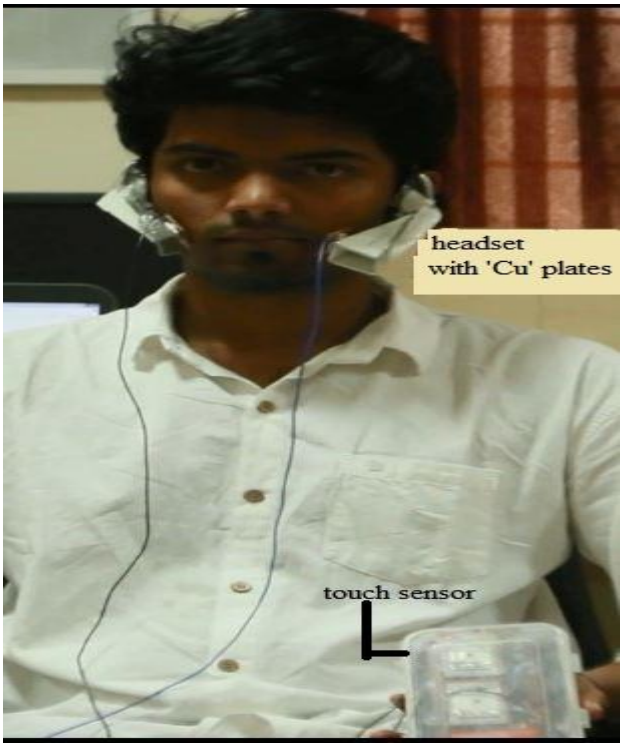

Figure 2: Portable System

All the circuits used in the project are isolated from the person unlike continuous monitoring of camera in case of eye ball tacking system, face mask used in some proposed solutions resulting in discomfort, etc. So the person using this product doesn't feel any discomfort nor malfunctioning or sudden breakdown of circuits result in any harm to the person thus making this product most reliable.
This paper proposes a different approach for the practical implementation of Home automation and wheel chair navigation [8]. It is called interactive board.

There are four modes of operation, viz. home automation, television, wheel chair mode, emergency and messages mode.

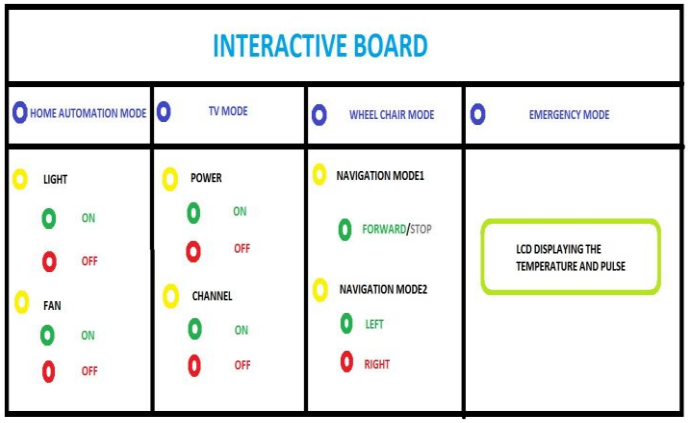

Figure 3: Interactive Board

The Interactive board shows the status of all the units through the Led's and helps the user to control the system. As the user can't remember the sequence of these gestures this interactive board makes the task easier for him.

- **BLUE LED** represents the present mode in which the person is.
- **YELLOW LED** represents sub-mode in each mode.
- **GREEN** and **RED LED** represent the task in each sub-mode.

The left touch sensor is used to switch between modes and sub-modes. A single left touch enables switching between sub-modes and long left touch enables switching between modes. The right sensor is used to switch between the tasks within the same sub-mode. **There is a special gesture to switch off all the modes in case of eating, etc.**

Though the no. of gestures are limited to two, this algorithm enables to handle a large no. of tasks.

Figure 4: Cad Model of Wheel Chair

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III. TOP-LEVEL BLOCK DIAGRAM

TOP LEVEL BLOCK DIAGRAM

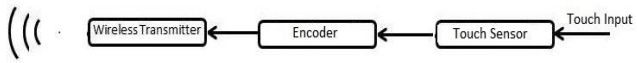

Figure 1 : Touch Sensor Input

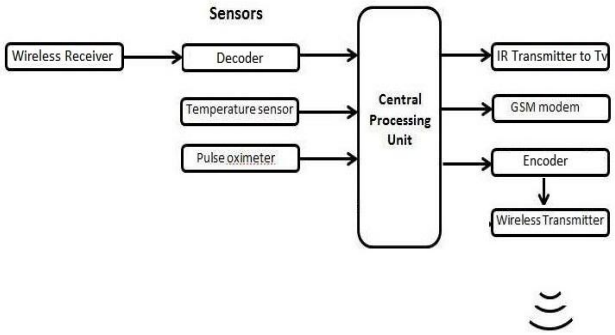

Figure 2 : Overall block diagram of master unit

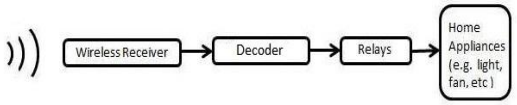

Figure 3 : Slave unit (Home automation)

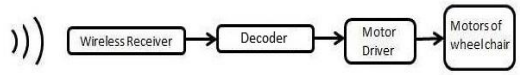

Figure 4 : Slave unit (Navigation)

Figure 5: Top level block diagram

The interactive board is placed in front of the person. The current mode of operation and the task is indicated by a LED. This makes it easier to switch between the modes. The light and fan in home automation mode are driven using relays. Motor driver ICs are used to drive motors of the wheel chair. A pulse sensor is interfaced with a second controller which continuously monitors the pulse rate of person. If the pulse rate exceeds safety limit, then an emergency message is sent to a caretaker via GSM modem which is interfaced with second controller.

IV. IMPLEMENTATION

A. Hardware Implementation

Capacitive Touch Sensor

A headset is mounted on the person with two copper plates to detect the touch of the cheeks due to the movement of the tongue. The touch acts as an input to the capacitive sensor AT42QT1010.When the touch pad is pressed, the body's capacitance gets added to the Capacitance Cs thus increasing the overall capacitance resulting in logic high, whenever a touch is detected. This logic is transmitted wirelessly to the micro-controller as an input. The sensitivity of the circuit by varying the capacitor Cs.

Figure 6: Capacitive Touch Sensor

Wireless Transmitter

A wireless radio frequency (RF) transmitter is made using HT12E Encoder and ASK RF Module. Wireless transmission can be done at 433Mhz or 315MHz frequency.HT12E Encoder IC will convert the 4 bit parallel data given to pins D0 – D3 to serial data and will be available at DOUT. This output serial data is given to ASK RF Transmitter. Address inputs A0 – A7 can be used to provide data security and can be connected to GND (Logic ZERO) or left open (Logic ONE). Status of these Address pins should match with status of address pins in the receiver for the transmission of the data. Data will be transmitted only when the Transmit Enable pin (TE) is LOW. 750kΩ resistor will provide the necessary external resistance for the operation of the internal oscillator of HT12E.

Wireless Receiver

ASK RF Receiver receives the data transmitted using ASK RF Transmitter. HT12D decoder will convert the received serial data to 4 bit parallel data D0 – D3. The status of these address pins A0- A7 should match with status of address pin in the HT12E at the transmitter for the transmission of data. The LED connected to the above circuit glows when valid data transmission occurs from transmitter to receiver. 51KΩ resistor will provide the necessary resistance required for the internal oscillator of the HT12D.

Micro-Controller

The received input is processed by the micro-controlled to control various tasks .The 40-pin TIVA-C provides the ease to control large no. of outputs. The micro-controlled is programmed as to control various tasks such as switching on and off lights and fans, navigation of wheel chair, television control (power control, channel browsing, etc.) Apart from these, the micro-controller has an input from pulseoxi-meter which when exceeds the normal heart rate alerts the caretaker with a message through gsm module.

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Relay

The output from the micro-controller is communicated wirelessly with the relay switch. A relay is used wherever a small low power device or power supply needs to switch on a much larger one, usually completely isolated from the signals power source, or at a much higher voltage than the signal could provide. Here two relays are used for switching of light and fan.

Pulse Meter

A pulse meter is designed to continuously monitor the pulse rate of the person. The pulse meter works on the principles of pulse-oximetry. An active band pass filter is designed using TI quad op-amp IC LM324. The gain of filter is 4300 and the cutoff frequencies are 0.8Hz and 2.8Hz. The output of the filter is then fed to internal ADC of the microcontroller for further.

B. Software Implementation

The flowchart showing switching between different modes (home-automation, TV, wheel-chair, emergency), sub-modes and tasks.

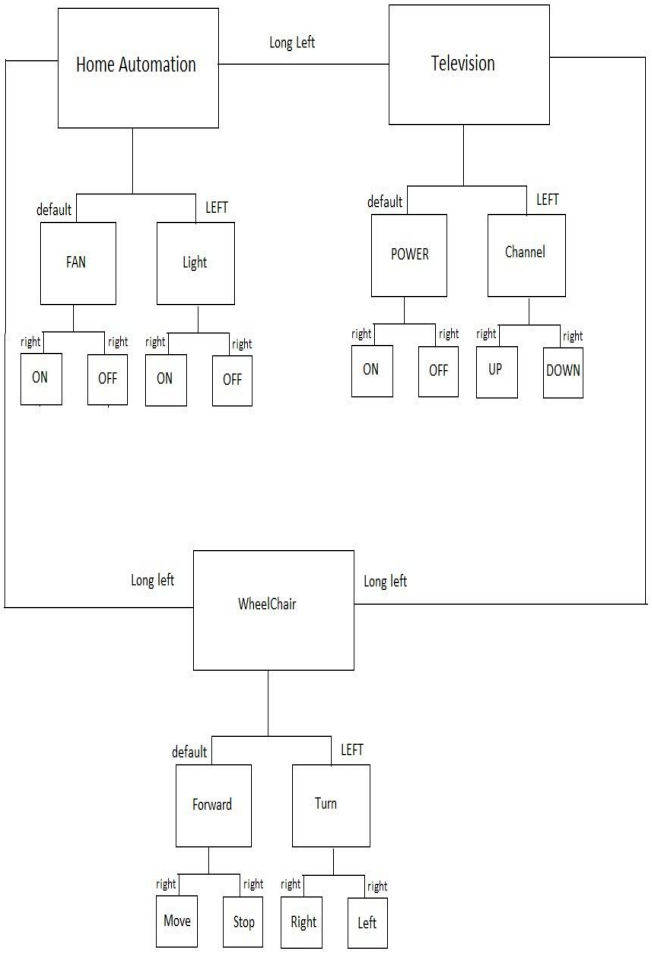


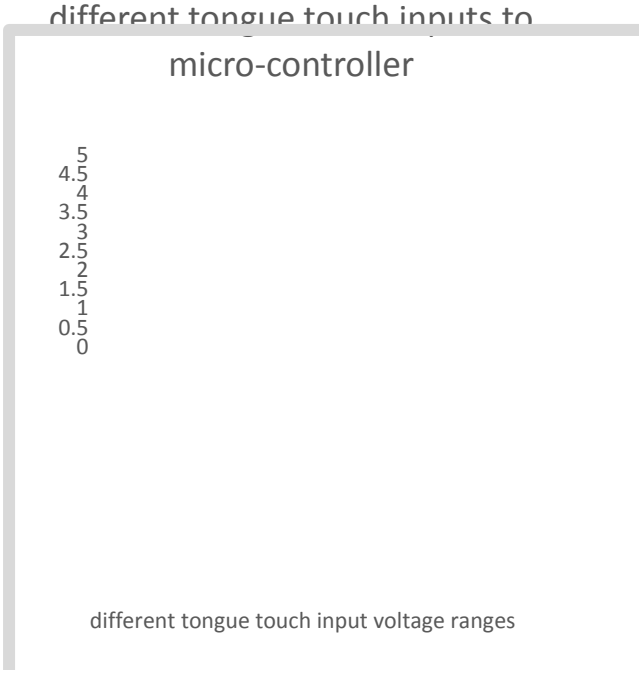
Figure 7: Flowchart of algorithm (Interactive Board)

The same idea can be extended to control smartphones, laptops, etc. [9] [10].

V. RESULTS

Different tongue touch input voltage ranges

As seen from the figure the difference between the normal tongue touch and that of a quadriplegic doesn't differ much and only intentional touches act as an input whereas undesired touches which may occur during sneezing, coughing, etc. aren't detected as an input.



A snapshot of the interactive board which shows that the user is currently in wheel-chair mode (indicated by blue-led), navigation-1 sub mode (indicated by yellow led) and the task forward being performed (indicated by green led).

The green led in home automation mode shows that the light has been switched on previously.

Figure **8: Snapshot of Current status of interactive board**

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VI.CONCLUSIONS

Although developments have already been made in the field of quadriplegic rehabilitation system, they are not quite full filling in terms of the ease of use and convenience. Also such systems are quite expensive and out of reach of most rural people. Here an attempt is made to design a rehabilitation system which enables the user to gain independence while performing regular tasks in day to day life.

This project is intended to design a system which can be controlled by movement of tongue, which is very useful for handicapped and paralyzed persons. This device could revolutionize the field of assistive technologies by helping individuals with severe disabilities such as those with high level spinal cord injuries return to rich, active, independent and productive lives.

The system consists of capacitive touch sensor, which can be used to control various devices such as light, fan, TV, etc. and can be used for navigation by a wheel chair. In addition to this, monitoring of health parameters, and emergency SMS to care takers can be done. This is the complete rehabilitation solution for the quadriplegics, which is not available in the market. Thus this model helps severely paralyzed person in reducing his/her dependency on others.

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