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Head Movements Based Control of an Intelligent Wheelchair in a Street Environment

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Abstract:

It presents a user-friendly human machine interface (HMI) for hands-free control of an electric powered wheelchair (EPW). Its two operation modes are based on head movements: Mode 1 uses only one head movement to give the commands, and Mode 2 employs four head movements. An EEG device, namely Emotive EPOC, has been deployed in this HMI to obtain the head movement information of users. The proposed HMI is compared with the joystick control of an EPW in a Street environment. The experimental results show that Control Mode 2 can be implemented at a fast speed reliably, achieving a mean time of 67.90 seconds for the two subjects. However, Control Mode 1 has inferior performance, achieving a mean time of 153.20 seconds for the two subjects although it needs only one head movement. It is clear that the proposed HMI can be effectively used to replace the traditional joystick control for disabled and elderly people aim at designing a simple cost-effective automatic wheelchair using MEMS technology for quadriplegics with head and neck mobility. The control system translates the position of the user's head into speed and directional control of the wheelchair. The system is divided into two main units: MEMS Sensor and programmed PIC Controller. The MEMS sensor senses the change in direction of head and accordingly the signal is given to microcontroller. Depending on the direction of the Acceleration, microcontroller controls the wheel chair directions like LEFT, RIGHT, FRONT, and BACK with the aid of DC motors.

Keywords—**Human Machine Interface (HMI), electric powered wheelchair (EPW), MEMS, EEG.**

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I. INTRODUCTION

1.1 Overview of the System

The current electric powered wheelchairs (EPWs) are mostly joystick-driven, and cannot fully meet the need of the disabled and elderly people whose autonomies are seriously affected by decline in their motor function and cognitive performance. Up to now, various hands-free HMIs have been developed for the disabled and elderly people to control EPWs by using shoulder, head and tongue motion, as well as eye tracking developed a visual based HMI for controlling a wheelchair by head gestures which were recognized by detecting the position of the nose on user's face. Used eye tracking and eye blinking obtained by a camera mounted on a cap to control a wheelchair.

Recently, a new EEG sensor, Emotive EPOC, has been available on the market to provide potential applications on hands-free HMIs. It has three suites: 'cognitive suite' to detect thoughts, 'expressive suite' to detect facial expressions and 'affective suite' to detect emotions, as well as a gyroscope to detect head movements, it was used to recognize four trained muscular events to steer a tractor:

(i) Eyes looking to the right and jaw opened,
(ii) Eyes looking to the right and jaw closed,
(iii) Eyes looking to the left and jaw opened,&
(iv) Eyes looking to the left and jaw closed.

The successful deployment of the IWs relies on their high performance and low cost.

1.2 Motivation

The aim of this project is to contribute to the research and implementation of technologies that can improve the quality of life of disabled and senior individuals that depend on locomotion devices to attain mobility. In present day society, the available means on the market have proven to assist a considerable portion of these individuals in a very satisfactory way. The goal of this research proposal is to adapt the existing solutions in a way that the minorities consisting of severe handicapped patients become highly independent in everyday locomotion activities.

1.3 Objective

The main objectives of this work are related to the study and development of an intelligent wheelchair (IW), based on the adaptation of a commercial electric wheelchair with hardware flexibility. Sensorial and control system implementation, as well as navigational methods and multimodal interface design are the core research focus of this project.

1.4 Back Ground and Existing System

Various methods have been proposed for allowing disabled persons, including a quadriplegic to control a motorized wheelchair. There are proposed methodologies in recent times which involve various gestures like hand gesture, accelerometer & voice controlled, EEG based system etc.

A. Hand Gesture

In this paper, they utilized the acceleration data to recognize the hand gestures and then transfer the gesture information which indicates certain motion commands into the wheelchair's smooth motions. It's a trial method to realize the natural interaction for the older and handicapped with the wheelchair through the hand gestures.

B. Accelerometer and Voice Controlled

This work describes a wheelchair for physically disabled people & developed it using voice recognition kit and MEMS motion sensor. A user dependent voice recognition system had been integrated in the wheelchair.

Intelligent Wheel Chairs

A vast amount of projects related to intelligent wheelchairs has been published over time, many of them being still under development in the last years. Although the first publications regarding intelligent wheelchairs date back to 1982, it was only in the last decade that this research area started to grow and evolve.

Figure: 1.1 Wang Wheel Chairs

II LITERATURE SURVEY

2.1 Eye motion tracking for wheelchair control

- Researchers continue to restore some functions lost by handicapped people using some powered electrical and robotic wheelchairs.
- Presents an application of eye tracking method to such wheelchairs the coherence algorithm tracks the movement of eye towards left or right.
- The eye blinking feature is also used by the algorithm to control the starting and stopping of wheelchair.
- Eye tracking is a technique whereby an individual's eye movements are measured so that the researcher knows both where a person is looking at any given time.
- The wheelchair can be controlled to move in that direction by giving commands to the wheelchair.
- Theses commands are transferred to the wheelchair using electrical signals which are used the drive the left or right motor of the wheelchair.
- The electrical signals are transferred to these motors using some hardware ports, called the communication ports.
- The eye motion tracking hardware includes a USB web camera which is mounted on a cap worn by the user.
- The camera has inbuilt light source, so that it can capture bright images if darkness appears under the cap.
- The algorithm extracts the pixels which lie on the vertical edges of the rectangular area selected by the user.
- The user blinks his eyes for a second, then the wheelchair starts or stops moving.

Advantage

- The ability to detect eye movement even when they are closed
- High accuracy and nearly unlimited resolution in time
- User friendly
- Reduces the human activity
- Reduces the physical strain

Disadvantage

- Poor gaze direction accuracy compared to video tracker, relatively costly
- Burden to user, here measuring time is limited to approximately 30 to 60.They have limited Lifetime.

2.2 Steering a Tractor by Means of an EMG-Based Human-Machine Interface

- An electromiographic (EMG)-based human-machine interface (HMI) is a communication pathway between a human and a machine that operates by means of the acquisition and processing of EMG signals.
- The HMI took into account only the detection of four trained muscular events on the driver's scalp: eyes looking to the right and jaw opened, eyes looking to the right and jaw closed.
- The EMG-based HMI guidance was compared with manual guidance and with autonomous GPS guidance.
- The standard deviation between the manual guidance and the EMG-based HMI guidance differed only 7 cm, and this difference is not relevant in agricultural steering.
- Machine vision and multiple sensors are positioning methods that have also been employed to achieve autonomous guidance.
- Employment of human-computer interfaces (HCIs) and brain-computer interfaces (BCIs) has allowed

Advantage

- An easier installation and removal
- A simpler calibration
- A lower price
- Capability of this system to detect fatigue or sleepiness from the EEG signals.
- Safer farm work

Disadvantage

- When the user is attempting to move the wheelchair by gazing at the screen, he would not actually be seeing where he is going.

2.3 Head-Computer Interface: A Multimodal Approach to Navigate through Real and Virtual Worlds

- A novel approach for multimodal interaction which combines user mental activity user facial expressions and user head movements
- The proposed approach doesn't make use of optical techniques. Furthermore, in order to make human communication and control smooth, and avoid other environmental artifacts, the used information is non-verbal.
- The head's movements (rotations) are detected by a bi-axial gyroscope
- The expressions and gaze are identified by electromyography and electro ocular graphy; the emotions and the thoughts are monitored by electroencephalography.
- The proposed approach we developed an application where the user can navigate through a virtual world using his head.
- The developed application was conceived for a further integration with an electric wheelchair in order to replace the virtual world with a real world.

Advantages:

- This approach is that arbitrary new information sources can easily be integrated into the interface,
- The approach facilitates an easy integration of additional input modules without having to modify the integration algorithm itself.

Disadvantage:

- The use of speech and gesture recognition as well as combinations of various input modalities,
- The mouse and the scene view is modified with reference to the current navigation mode. Depending on the current context mouse and touch screen was support feasible

III PROPOSED DESIGN

3.1 System Hardware Structure

The picture of our RoboChair that was built in 2004 and has the following components:

- 6 ultrasonic sensors at a height of 50cm for obstacle avoidance (4 at the front and 2 at the back);
- DSP TMS320LF2407-based controller for motion control of two differentially-driven wheels;
- A local joystick controller to connect to A/D convert of the DSP-based controller;
- A Logitech 4000 Pro Webcam for recognizing the user's head gesture; and Inter Pentium-M 1.6G Centrino laptop with WindowsXP installed to analyze the head gesture.

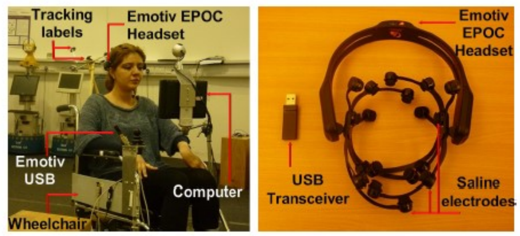

Figure: 3.1 Prototype of the Robochair Used In This Research

Intelligent control mode:

This is to be developed currently in this project. Under this control mode, our RoboChair is controlled by the HGI with an obstacle avoidance module embedded in the DSP motion controller.

Manual control mode:

This is already built in our RoboChair. Under this control mode, our RoboChair is controlled by the joystick that connected to the DSP motion controller with the obstacle avoidance module embedded.

3.2 User Interface

The interface architecture provides the mechanism for interaction between the user and the wheelchair. Voice commands provide a convenient mode of interaction. However speech controlled systems traditionally monitor the speech recognizer for a list of known keywords to activate specific functionalities of the intelligent systems. This tends to be very brittle and sensitive to the speech recognition performance, as well as requiring the user to memorize a set of commands

Voice Recognition

Windows 7 computer is used to get the voice translated into commands. This way use the library "Microsoft Speech Object Library.dll", bundled inside Windows 7. It allows us to continuously get audio from a microphone and translate that audio into plain text readable by a machine, without any need to send the audio to any server.

- MEMS accelerometer unit this unit is the sensing unit. Here based on the direction in which the motion sensor is moved there will be change in output voltage. This output voltage is given to signal conditioning circuit.
- Voice Recognition Kit The voice recognition kit REF stores the voice command in memory. Then analog voice signals are converted into digital signals using ADC.

IV WHEELCHAIR MAINTENANCE AND TYPES

4.1 Wheelchair Maintenance

Wheelchair maintenance tools will come in handy when performing maintenance on any wheelchair or wheelchair part. Wheelchair Maintenance is essential when it comes to saving money. Unless you want to be a new wheelchair every time one little part breaks you will need to do some wheelchair maintenance. This is much easier when you have the proper tools.

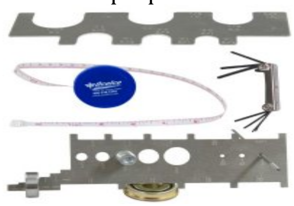

Figure: 4.1 Wheelchair Maintenance

4.2 Wheelchair Types

1. Economy Wheelchairs
2. Standard Wheelchairs
3. Lightweight Wheelchairs
4. Lightweight Adjustable Wheelchairs
5. Rigid Wheelchairs
6. Reclining Wheelchairs
7. Tilting Wheelchairs
8. Pediatric Wheelchairs
9. Bariatric Wheelchairs

1. **Economy Wheelchairs**

Economy wheelchairs are a class of wheelchairs that are not normally promoted much by retailers and while they will provide basic independent and aided mobility they are not considered the best choice for users who need a wheelchair for all their mobility needs on a daily basis. These chairs are generally reasonably good quality products that will function perfectly fine for many users.

2. Standard Manual Wheelchairs

Standard wheelchairs are the most basic of the categories that self propulsion is an option. Standard wheelchairs are intended for short term use and although seating systems can be added to the wheelchair this category isn't often chosen for those who will be using a wheelchair on a regular basis. The advantage of the standard wheelchair is it is sturdy and inexpensive.

3. Lightweight Manual Wheelchairs

Figure: 4.2 Sunrise Breezy Wheelchair

Lightweight wheelchairs are by far the most common wheelchairs in use today. They are relatively inexpensive and offer a wide range of options and configurations to make the user as comfortable as possible and the chair functional for independent mobility with the minimum of effort by the user.

4. Lightweight Adjustable Folding Wheelchairs

Figure: 4.3 Lightweight Adjustable Wheelchairs

Many of the ultra light folding wheelchairs are quite similar to the lightweight wheelchairs but offer more adjustability for even more fine tuning to the user's needs. They are more expensive than the ultra light models but are basically ordered the same way with similar options. The difference is really most noticeable after delivery when all the adjustments become evident while setting the chair up.

V WHEELCHAIR PARTS & ACCESSORIES

5.1 Wheelchair Parts & Accessories

- Frame Styles
- Arms
- Footrests
- Wheels
- Brakes
- Casters
- Options

5.1.1 Manual Wheelchair Frames

The frame of the wheelchair is the component that holds all the other components together and determines the type of wheelchair that will result from assembly. Standard weight wheelchairs will usually have steel frames, light weight wheelchairs will usually have aluminum frames and ultra light frames can be made of either aluminum or titanium frames.

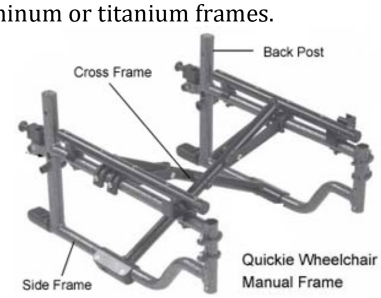

Figure 5.1: Manual Wheelchair Frames

5.2 Wheelchair Arm Rests

There are a variety of wheelchair arm rests on the market to meet the needs of various types of wheelchair users. Armrests on wheelchairs have various functions depending on the user's needs but the most common are aids for transferring, comfort while sitting and weight shifting.

1. Armrest Height

Fixed height arms are not as common or as useful as adjustable height arms as the user's elbows, which the wheelchair arms are supposed to support for comfort, are not all the same height. Arm lengths are, of course, longer on some people than others and even if they are the same length they may be different heights depending on the thickness of the cushion they use.

2. Fixed Arms

Fixed arm rests on wheelchairs are welded or otherwise permanently attached to the frame of the wheelchair. Most wheelchairs today do not offer fixed arms with the exception of chairs designed for institutional use.

3. Flip Back Arm rests

Flip back arms are hinged at the rear connecting point to the seat frame of the wheelchair and when a latch is released at the front attachment point will flip to the rear of the wheelchair and out of the way for sliding transfers or to get up close to a table or desk.

5.3 Wheelchair Footrests

There are two or three types of foot support for a wheelchair. The two most common are generally known as "footrests" and "legrests". A footrest consists of a footrest hanger and a footplate for the user's foot to rest on and a legrest has a "calf pad" mounted on an elevating hanger to support the lower leg.

5.4 Manual Wheelchair Wheels

The rear wheels on a manual wheelchair come in several different sizes and a couple of different styles as normal options. Generally speaking the larger the wheel, the easier propulsion will be and the wider the wheel, the better they will be able to roll over softer terrains such as lawns.

5.5 Wheelchair Wheel Locks

Contrary to popular belief, wheel locks on wheelchairs are not brakes. Brakes would be used to slow down and stop a wheelchair but that is not the purpose of wheel locks. Wheel locks are more like parking brakes; designed to keep the wheelchair in place when waiting or transferring in and out of the wheelchair.

Figure 5.2: Wheelchair Wheel Locks

5.6 Wheelchair Casters

Wheelchair casters come in a variety of diameters and widths and each different style and size will have its own attributes that make it appropriate for different applications. The purpose of wheelchair casters is to stabilize the wheelchair while the drive wheels (powered wheels on a power wheelchair & large hand rimmed wheels on a manual wheelchair) propel the wheelchair.

VI WHEELCHAIR ACCESSORIES

6.1 Wheelchair Wheel Lock Accessories

Wheel locks for wheelchairs have a couple of accessories that are of benefit to the user. These items are not really needed for the brakes to function but they will either make the wheel lock easier to use or provide a benefit to the user. While some of these options are available when the wheelchair is originally ordered, they can usually be purchased at a later date should the need for them arise.

Figure 6.1: Wheel Lock Accessories

1. Accu-grips

Accu-Grips are oversized, bright yellow brake tips. They give the user a bigger, brighter target to find when looking for their brakes. They are of great benefit to those whose eyesight is poor or those who have problems with their hands that may prevent them from being able to grip the wheel lock handles comfortably.

6.2 Wheelchair Safety Accessories

Safety in a wheelchair or scooter has to be one of the things that should be foremost in the minds of prescribers and purchasers. A mobility device that isn't safe for the user, or those around them, should be avoided. In cases where, for the most part, users are safe and competent in the use of their mobility equipment accidents can still happen and the products on this page have been created to minimize the occurrence of specific accidents for everyone's safety.

6.3 Wheelchair Trays

Wheelchair trays come in a variety of shapes, sizes and materials to provide answer several issues facing wheelchair users in their daily activities. They negate the need to roll up under a table to participate in activities such as eating meals, writing, reading, supporting communication devices and computers. In short they provide a work surface.

6.4 Manual Wheelchair Propulsion Assist Devices

Propulsion assist devices for manual wheelchairs can be great options for people who lack the strength and stamina to propel their wheelchairs throughout the day. While many people may move to a conventional power wheelchair when faced with propulsion problems while using their manual wheelchair, power wheelchair present some problems that are not easily overcome.

Figure 6.2: Wheelchair Propulsion Assist Devices

6.5 ONE ARM DRIVE SYSTEMS

One of the drawbacks of conventional manual wheelchairs is they are not really functional for users who lack the use of one hand or arm. Many people who require a wheelchair and have issues around the use of one of their arms usually end up purchasing powered wheelchairs in spite of the drawbacks presented by their weight, lack of portability and cost.

VII POWER WHEELCHAIR JOYSTICK MOUNTS

7.1 Joystick Mouse

Power wheelchair joysticks are the most common components used to drive the wheelchair and they have to be mounted in a position where the user is able to easily and comfortably access them for extended periods of time. A properly positioned joystick will enable the user to drive their power wheelchair more safely and reduce their fatigue over the day.

Figure 7.1: Joystick Mouse

1. Joystick Chin Mounts

Chin mounts are for people who use aren't able to use their hands to drive the power wheelchair. The chin mount is very similar to the midline mount but will often be mounted to the wheelchair back posts rather than the wheelchair armrests. Using the same small remote or compact joystick as the midline mount the joystick gimbal knob is often, but not always, replaced with a small cup-shaped gimbal that the user manipulates with their chin.

7.2 Joystick Gimbal Knob Options

The gimbal of a power wheelchair joystick is the part the user's hand or fingers move to tell the wheelchair how fast and which direction to go. The knob of the gimbal is available in several designs to provide the user with the most functional grip possible. While there is often the opportunity to choose the best gimbal knob when ordering a power wheelchair sometimes the best option isn't available from the manufacturer.

Standard Gimbal Knobs

Depending on the make of the power wheelchair, the gimbal knob that comes standard on the joystick will likely be a small round plastic ball about 1" in diameter, a straight sided rounded knob about 1" long or a 1" wedge shaped plastic knob with a flat top.

Round T-Bar Gimbal Knob

For people who are unable to grip the standard gimbal knobs the round T-Bar is often the answer. It is usually manufactured from sections of steel bars about 3/8" diameter and between 3" and 4" long. Normally the round bar is mounted at 90° to the user's arm but it can be mounted at an angle if needed.

VIII WHEELCHAIRS WORKING PRINCIPLE

8.1 Wheelchairs Components

Footrests:

Footrests support your feet and lower legs. They can be fixed, folding or swing-away and come in many different styles.

Armrests

Armrests are places to rest your arms when you're not moving. They can be wraparound, full-length or desk-length; fixed or height-adjustable; removable or flip-back. It is important because armrest position can alter the way you propel your wheelchair.

Tires:

Tires are most commonly air-filled (pneumatic) and therefore lightweight. They also require maintenance and can puncture. If you maintain them, this is usually the best choice

Pushrims:

There are a variety of pushrims with different friction coatings and shapes that may assist with propulsion and reduce the risk of injury to the hand.

8.2 Wheelchairs Electronics

A wide array of power options, from elevating or tilting/reclining seats to drive controls with all sorts of accessible choices; enable you to make your power chair your own.

2. Blue Sky Designs

Mountn Mover

Personal electronics are only useful if they are accessible which is why Mount'n Mover is independently movable by the user with no tools required.

8.3 Set of Tools

Your owner's manual will tell you the exact tools you will need but here are the most common tools used for basic wheelchair maintenance and repairs:

- Phillips and flat head screw driver
- Set of Allen wrenches (Hex keys)
- Crescent wrench
- Spoke wrench

All-purpose silicone or Teflon®-based lubricant spray Tire repair kit (if you have pneumatic tires) 2 tire levers spare inner tube (if appropriate) bicycle tire hand pump or small electric tire pump with gauge

IX EXPERIMENTAL RESULT

9.1 Speech Recognition Engine

The dsPIC30F Speech Recognition Library was used as the speech recognition engine of this project. The dsPIC30F Speech Recognition Library allows the incorporation of speech recognition in an embedded application program running on a dsPIC30F device. A predefined list of words controls the application with only a modest amount of RAM and program memory. The word list is created with the dsPIC30F Speech Recognition Library Word Library Builder.

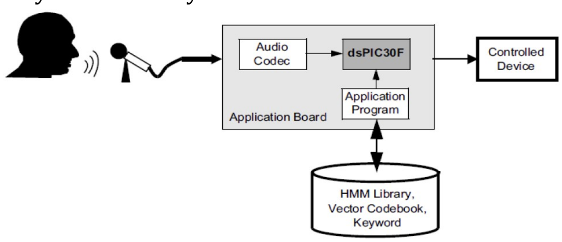

Figure 9.1: Overview of Speech Recognition

The Speech Recognition Library provides isolated, speaker independent word recognition of US English. It allows a user to control an application through a set of fixed, voice commands.

9.2 Powered Wheelchair Interface

The printed circuit board (PCB) in figure 21 was designed and fabricated to interface the controller with the powered wheelchair. This PCB houses two dsPIC30F microcontrollers dedicated for speech recognition and FFT analysis. The dsPIC performing the speech recognition is connected to the Si3000 voice CODEC for sampling the input voice from its MIC input.

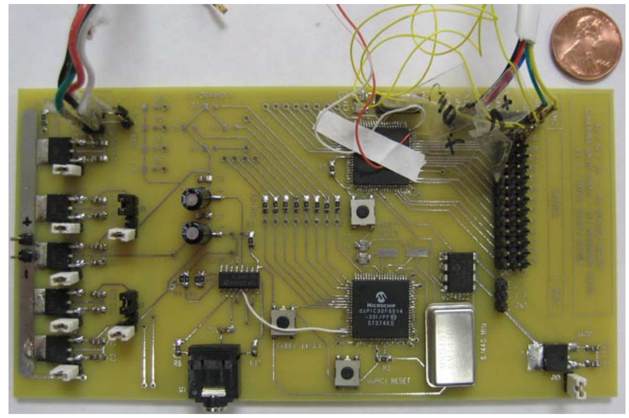

Figure 9.2: Hum-Power Controller Board

9.3. Ambient Noise Test Results

The analysis for the ambient noise effect on the recognition accuracy of the Hum-power controller was done with MATLAB on the "stop" command. The user was asked to repeat this word for 20 times and a 4 second wave-file was recorded for each instant.

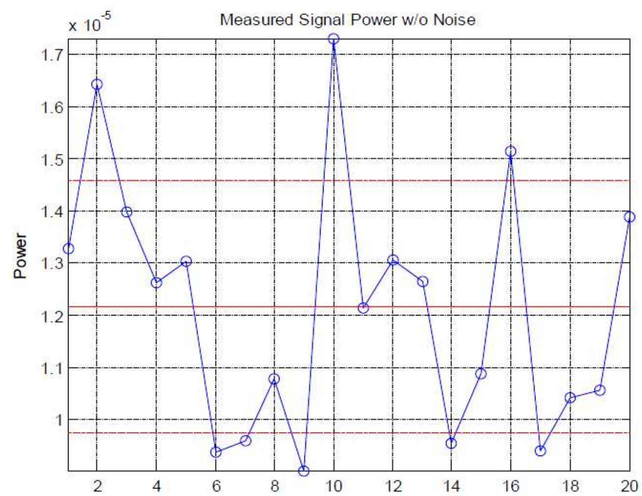

Figure 9.3: Measured Signal Power without Added Noise

To simulate higher ambient noise a white Gaussian noise source was used (2 feet away from the microphone) to increase the noise in the background while recording the commands for analysis. The first recorded "stop" command was then played back for 20 times and at each instance the level of white Gaussian noise was increased by 5% from 0 to a full 100%.

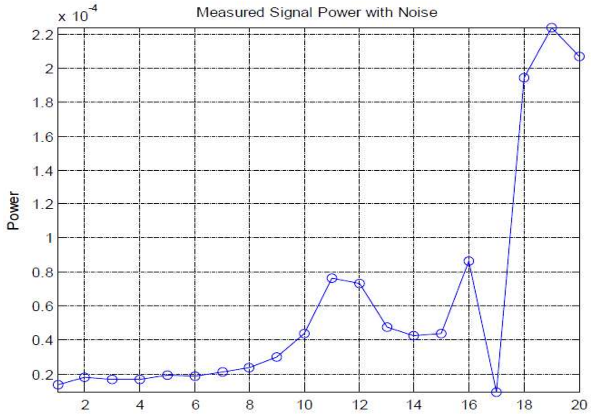

Figure 9.4: Measured Signal Power at Different White Gaussian Noise Levels

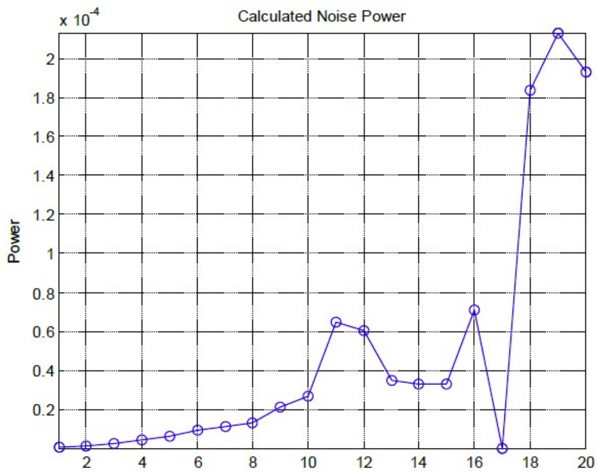

Figure 9.5: Calculated Noise Power from The Measured Noisy Signal

The power of Gaussian noise was calculated using the known signal power and the power of the measured noisy signal. This shows that the power of the Gaussian noise was increasing as expected.

CONCLUSIONS

In this paper, a novel head gestures based HMI is proposed for hands-free control of EPWs. It uses head movements detected by the motion data obtained from the gyroscope of an Emotiv sensor. It has two control modes, one mode uses only one head movement ('up' or 'down') and the other one employs four head movements ('up', 'down', 'right' and 'left'). Four control commands were implemented, namely 'going forward', 'turning right', 'turning left' and 'stopping'. In both control modes, the user does not have to maintain the head movement during the control command. Experimental results show that the proposed HMI is reliable for controlling a wheelchair.

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