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Mind Controlled Wheelchair

Utkarsh Sinha* and Kanthi.M*

Abstract : The paper deals with engineering an electric wheelchair from a common wheelchair and the development of a BCI system (Brain-Computer Interface) between the electric wheelchair and the human brain. The target populations for the mind controlled wheelchair are the patients who are paralyzed below the neck and are unable to use conventional wheelchair interfaces. A portable EEG headset, MCU and firmware signal processing together facilitate the movement of the wheelchair by processing the user's brain activity and eye blinks' frequency. This paper reports the creation of a cost efficient solution, later intended to be distributed as an add-on conversion kit for a common manual wheelchair. A Neurosky Mind wave headset is used to pick up EEG signals from the brain. This is a commercialized version of the Open-EEG Project. The signal obtained from EEG sensor is processed by the ARM microcontroller FRDM KL-25Z, a Freescale board. The microcontroller takes decision for determining the direction of motion of wheelchair based on floor detection and obstacle avoidance sensors mounted on wheelchair's footplate. The MCU shows real time information on a color LCD interfaced to it. Joystick control of the wheelchair is also provided as an additional interface option that can be chosen from the menu system of the project.

Keywords : Brain-Computer Interface(BCI), Open Electroencephalography (EEG), Microcontroller Unit (MCU), Firmware Menu System.

1. INTRODUCTION

Millions of people around the world suffer from mobility impairments [1]. People having mobility impairments need new devices with sophisticated technologies to help them for comfortable mobility. Wheelchair users having mobility impairments experience a high level of movement and functional limitation. Many patients are unable to control the powered wheelchair using conventional interface and also they are deemed incapable of driving safely [1]. Brain controlled wheelchair is being developed to provide mobility to the individuals who find it impossible to use a powered wheelchair due to motor, sensory, perceptual, or cognitive impairments [1]. Advancements in robotics, senor technology and artificial intelligence promises enormous scope for developing an advanced wheelchair.

Brain computer interface (BCI) are systems that communicate between human brain and physical devices by translating different patterns of the brain activity into commands in real time [2]. The electrical activity of the brain is monitored in real time using an array of electrodes, which are placed on the scalp in a process known as electroencephalography (EEG) [1]. Traditional EEG sensors are expensive and their use is limited only to hospitals and laboratories. The electrodes of EEG sensors require conductive gel on skin in order to facilitate reading signals.[2] The advantage of using a portable EEG brainwave headset is that it uses a dry active sensor technology to read brain electric activity. Traditional gel based EEGs can take up to 30 minutes to start acquiring data while the Neurosky headsets are ready to go in seconds. For this reason, headset based on Neurosky technology is cost-effective and easy to handle. The on board Think Gear IC processes raw signals, filters the noise and digitizes the signal [2-5]. The control system design for the wheelchair using various methods of BCI as well as speech and gesture recognition are

* Manipal Institute of Technology, Manipal University, Manipal-576104, Karnataka, India *E-Mail: kanthi.hegde@manipal.edu, kanthi_hegde@yaho.com*

discussed [2- 8], but the actual implementations are not shown. The multipurpose manual wheelchair is designed to serve various purpose of the patient as well as elderly people [9]. A wheelchair is designed which is controlled through Electroculography. The movement of the wheelchair direction is restricted to particular direction based on horizontal and vertical movements of the eye. But practically, eye will also have some oblique movements for which the wheelchair is not satisfactorily responding for the movement in particular direction [10].

The proposed work deals with the engineering an interface between the human brain and an electric wheelchair using a portable EEG brainwave headset and firmware signal processing and filtering. The project eliminates the drawbacks of conventional EEG by using a dry sensor technology to pick up EEG signals instead of using a conductive gel and reducing the time it takes to setup. This project aims at creating a cost efficient solution, later intended to be distributed as an add-on conversion unit for a normal wheelchair. Doing so would be of Nobel importance to 'brain-active-body-paralyzed' patients providing them the independence of mobility.

The research gap of this project compared to the previous versions [1-10] are:

- The reduction in cost by making the design as a conversion kit for a regular wheelchair; the project doesn't reinvent the wheel, it instead builds on top of an existing framework and brings together the best of things. The mechanical modifications are narrowed down to a level where it can be reproduced easily and put on other manual wheelchairs.
- The project uses a mind wave headset instead of traditional EEG to acquire brain signals thereby reducing the set up time.
- The wheelchair's embedded subsystem uses a menu based GUI, this allows the wheelchair's control to be either mind wave controlled or joystick controlled; the two modes of operation makes it possible for this system to be useful for a wide range of disabilities in people.

2. METHODOLOGY

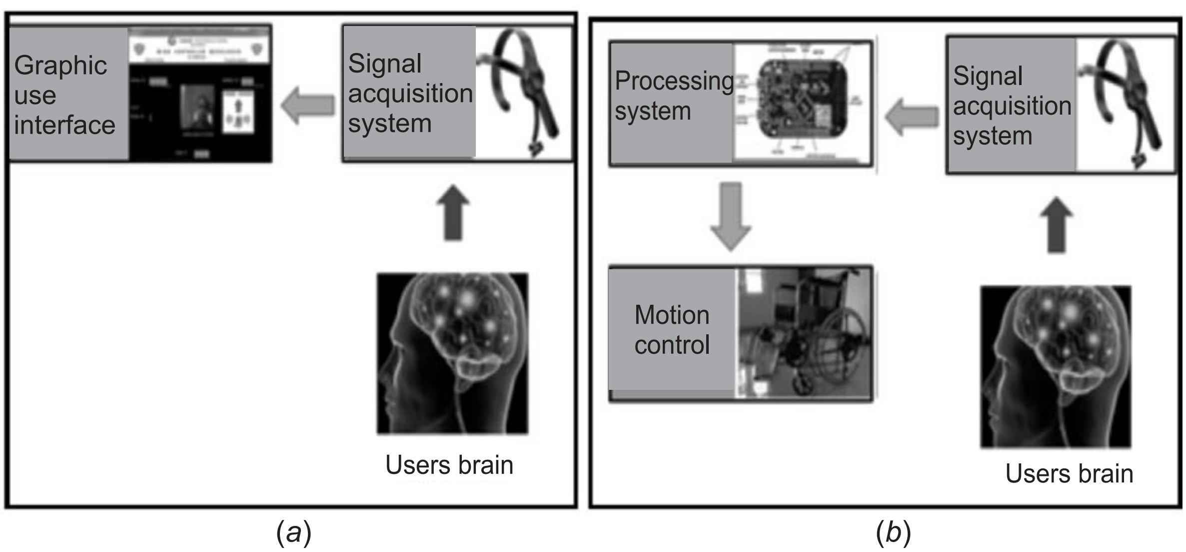


Figure 1: Conceptual block diagram: (*a*) Training for wheelchair using GUI (*b*) Mind controlled wheelchair

The Mind controlled wheelchair controls the direction and motion of wheelchair based on the decision taken by the user. The mind wave headset is used in the mind controlled wheelchair to pick up EEG signals from the brain. Manual wheelchairs are driven with the help of man power as the source of energy for moving the chair. The manual wheelchairs are driven by the user by using the rear wheels with additional rims called the "Push Ring" for movement by rotating forward or backward [9]. In the proposed wheelchair modification of manual wheelchair is done by mechanically coupling motors to rear wheels thereby making it an electric wheelchair. The active rear wheels are rotated by motors to the orientation that matches the current driving direction; the system employs differential drive. A differential drive uses two motors on either side of the wheelchair and a castor wheel on the front. When both the Left and Right Motors are forward biased, the wheelchair moves forward. For turning the wheelchair right, the Right Motor is given forward bias and the Left Motor is given reverse bias. Forward bias on the Left Motor and reverse bias on the Right Motor turns the wheelchair left. The duration and hence the degree of turn is controlled by the mind wave signals from the user. For turning purpose, full excitation is given to the drives. The level of excitation given to the drives for forward movement is controlled by heightening the attention and meditation level by of the brain by the user. This way the forward speed of the wheelchair is controlled. The conceptual block diagram of mind controlled wheel chair is as depicted in figure 1. The various components interfaced with the microcontroller to control the wheel chair are shown in Fig.2

A. Electronics and embedded subsystem

The Electronics and embedded subsystem comprises of the Neurosky's Mindwave Headset which is a portable EEG mobile headset used to pick up EEG signals from the brain of the user and transmit them to the microcontroller unit via Bluetooth. The Bluetooth module used for receiving the signals transmitted by headset is BlueSMiRF(RN-42) that is interfaced with the microcontroller used over USART. Figure 3 shows the algorithm for data acquisition by RN-42 (BlueSMiRF) from the mind wave.

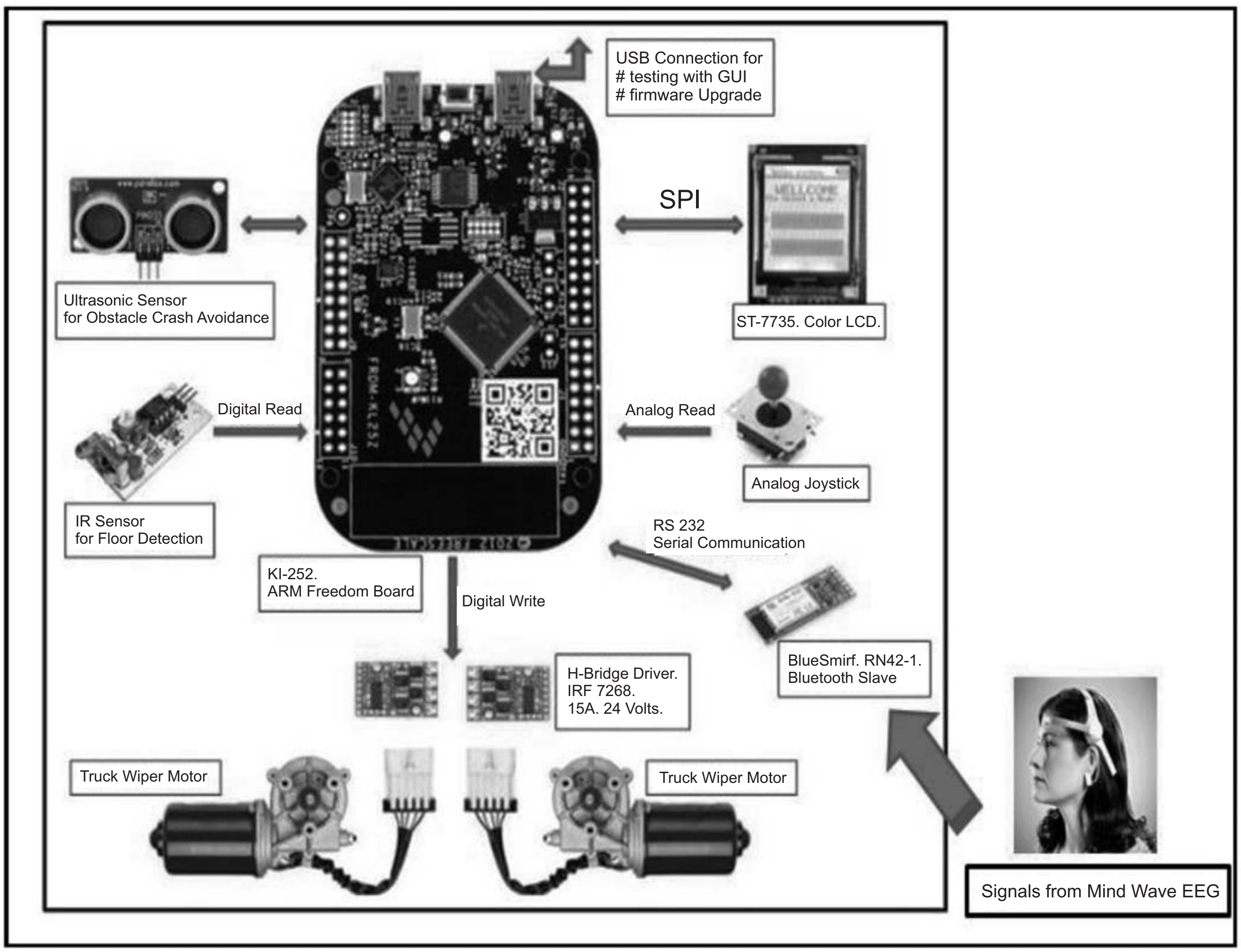


Figure 2: Sensory, processing and actuation systems

The data transmitted by the Mindwave Headset will be received by the the Computer's Bluetooth receiver. And all the data will be analyzed by the Level Analysis Platform. The Level Analysis Platform will extract the raw data using LabVIEW. In the LabVIEW data will be received from the port pin which they are giving the same port number for the Bluetooth receiver and LabVIEW in the back panel.

The microcontroller used is FRDM-KL25Z which is a Freescale Freedom development platform microcontroller board assembly. It features a Kinetis L series microcontroller built on ARM Cortex M0+ core [11]. H-Bridge MOSFET drivers are used to drive motors. The microcontroller forms an essential part of the processing system. The microcontroller in response to the signals picked up by EEG sensors compute the direction of motion. The microcontroller outputs the processed data to the user interface and motion control systems.

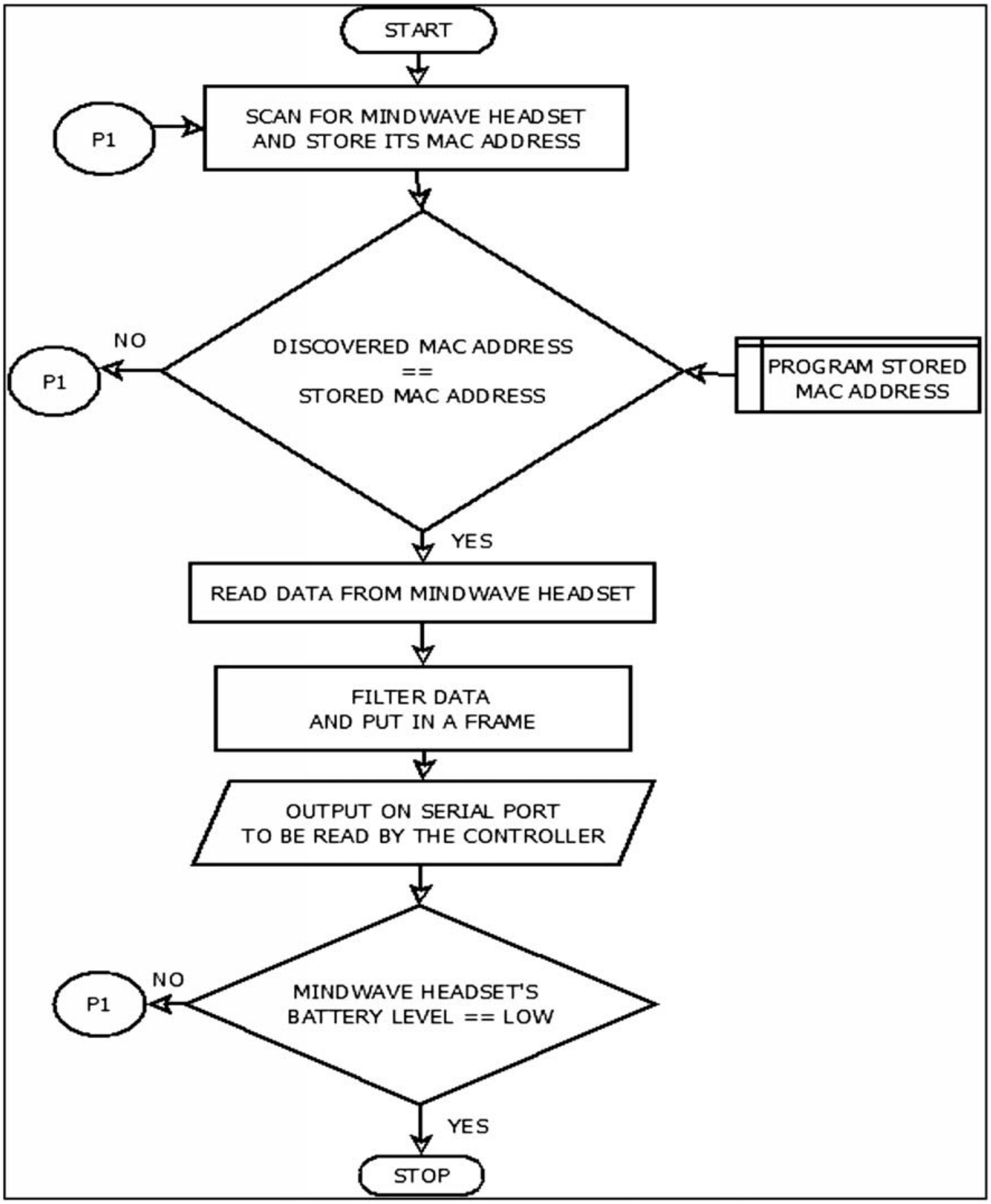
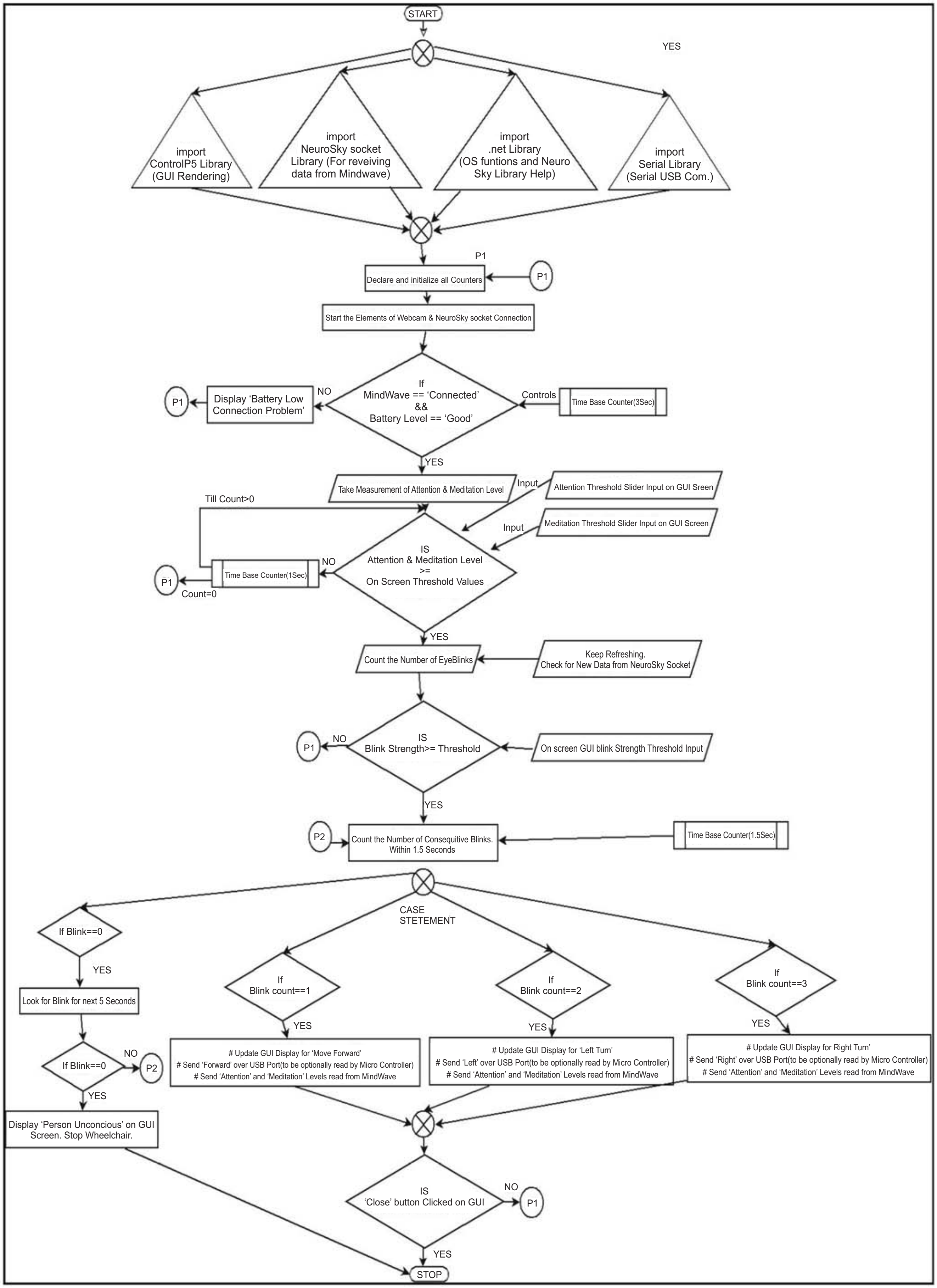


Figure 3: Data acquisition

B. Software and Data processing subsystem

Graphic user development is needed to provide Neuro feedback to individual in the form of visual stimulus. Using which they can control their brainwave output more easily and enable a more efficient control system [2],[4],[12].



Figur 4: Java Algorithm for training

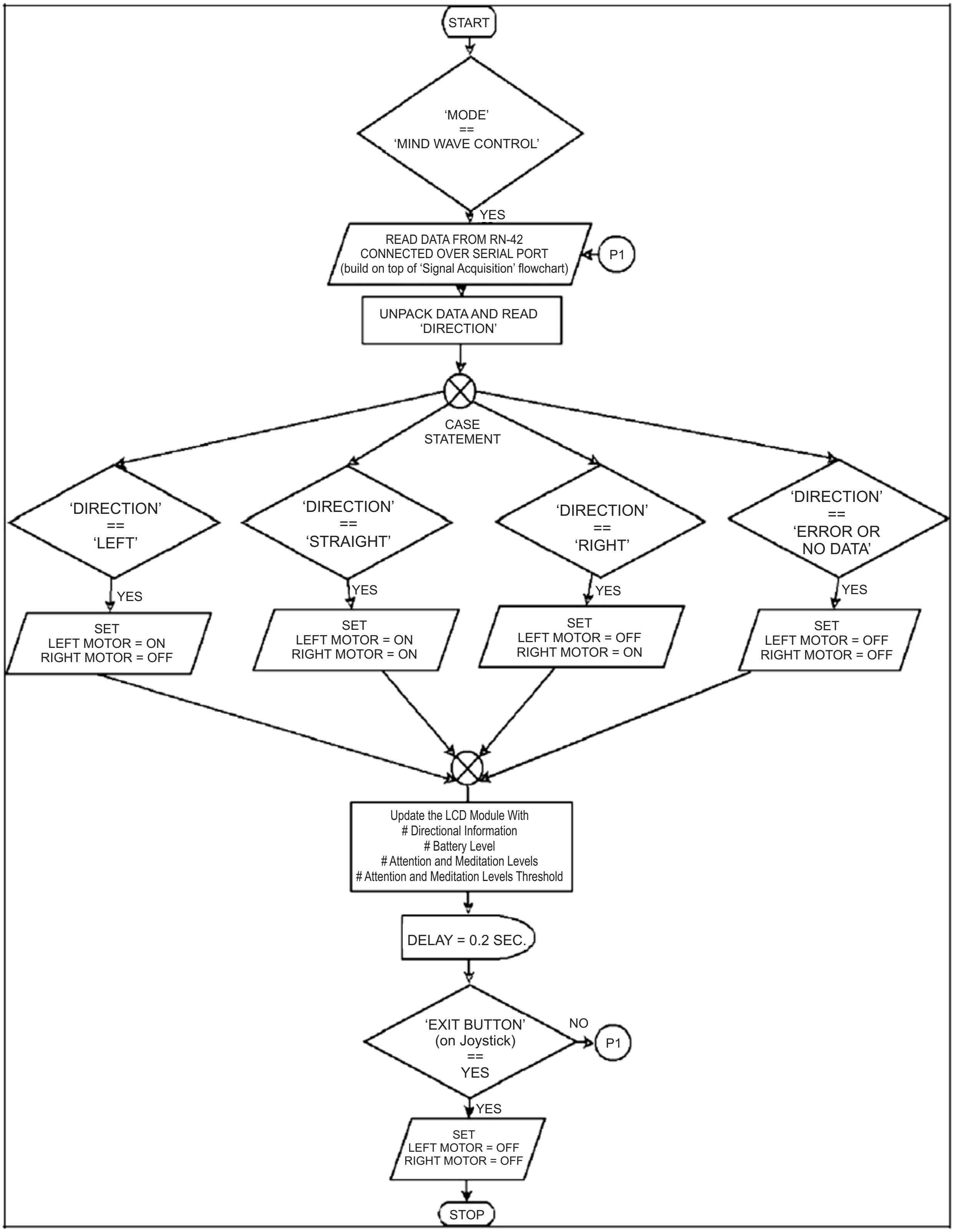


Figure 5: Algorithm for Data Processing and Control

Prior to letting the subject use the wheelchair, a training program to control the direction and speed of the wheelchair is formulated. A custom software is developed using Java. This software simulates a wheelchair environment on the PC screen. Figure 4 describes the algorithm of the Java program. Right, Left, Forward and Stop commands given by the disabled person are deciphered using algorithm shown in Figure5. The reverse movement is prohibited for safety reason. When a person blinks 2 times within 1 sec, the wheelchair turns Left. When a person blinks 3 times within 1 sec, the wheelchair turns Right. If the person blinks multiple times, that is, if the time interval blinks is more than a second, the wheelchair keeps moving normally forward.

However, the person needs to blink once at least in 5 seconds to keep the wheelchair moving. This is done so that the person shouldn't day-dream and meet with an accident. In order to keep the wheelchair moving, the patients 'Attention' and 'Meditation' levels should be at all times above a certain threshold. Person to person the attentive levels vary, so the GUI and the wheelchair, both have provisions to customize and set the threshold levels. The eye blink signal strength, attention and meditation level signal strength may vary from user to user and doesn't have a typical value associated with it. To overcome this and make it customisable to the user, the PC GUI provides sliders to set the threshold of these signal level. Training with the PC GUI will also facilitate the user to understand and exploit real-time varying 'Attention' and 'Meditation' levels of his brain to control the wheelchair. The values of the threshold empirically found with this PC based GUI can be entered on the Menu System GUI of the wheelchair. So, after training with the PC GUI, the user knows how to control the wheelchair and the wheelchair will have those values of person-varying signal strength threshold.

C. Mechanical subsystem

The manual wheelchair consists of driver wheels at the back and castor wheels in the front. The mechanical assembly that converts manual wheelchair to an electric wheel consists of DC truck wiper motors and mechanical parts. The DC Truck Wiper motors are coupled to the rear wheels. Figure 6 gives the electrical and mechanical modifications. The mechanical parts include:

- **Bracket for holding DC motor :** The assembly consists of two plates that hold the DC motor. The plates hinge to the frame above the castor wheels and hold the DC motor in Place.
- **Chains and sprocket :** The DC motor's shaft is welded to the front sprocket and conveys the rotatory motion of the motor to the Push Ring of the wheelchair through a chain. A gear reduction and size of sprockets is chosen based on the diameter and RPM of the wheelchair wheel. Thus, gear reduction of 1:1 is chosen This project has employed standard bicycle 22 cm chain-wheel as the gears. The use of a standard part is intended to make the procurement and manufacturing of this product simpler.
- **Push Ring coupling assembly :** The push ring is what the patient holds and rotates to move the wheelchair. A holding assembly with sprocket coupled to the push ring takes the motion from the DC motor and moves the wheelchair.
- **Electronics Mounting Plate :** A plate is mounted on the Anti-tip Bars of the wheelchair. This is where the electronics and battery is mounted.

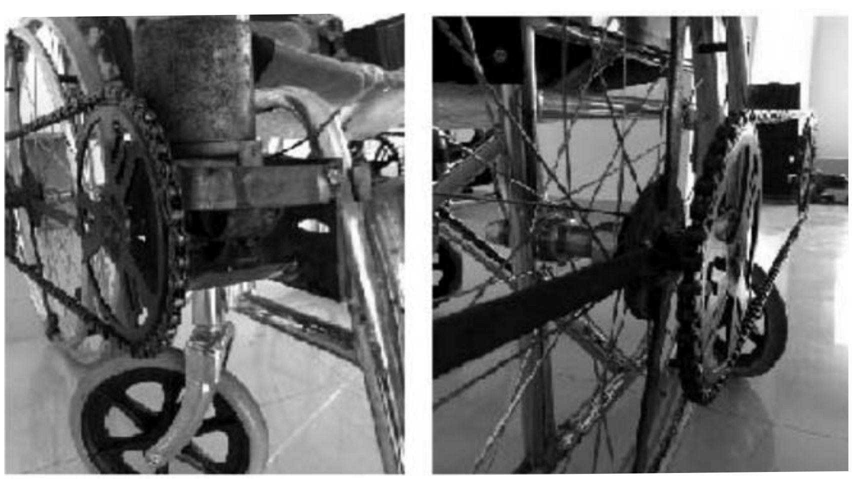


Figure 6: Electrical and mechanical modifications

3. RESULTS

Figure 7: Graphic user interface developed using Java

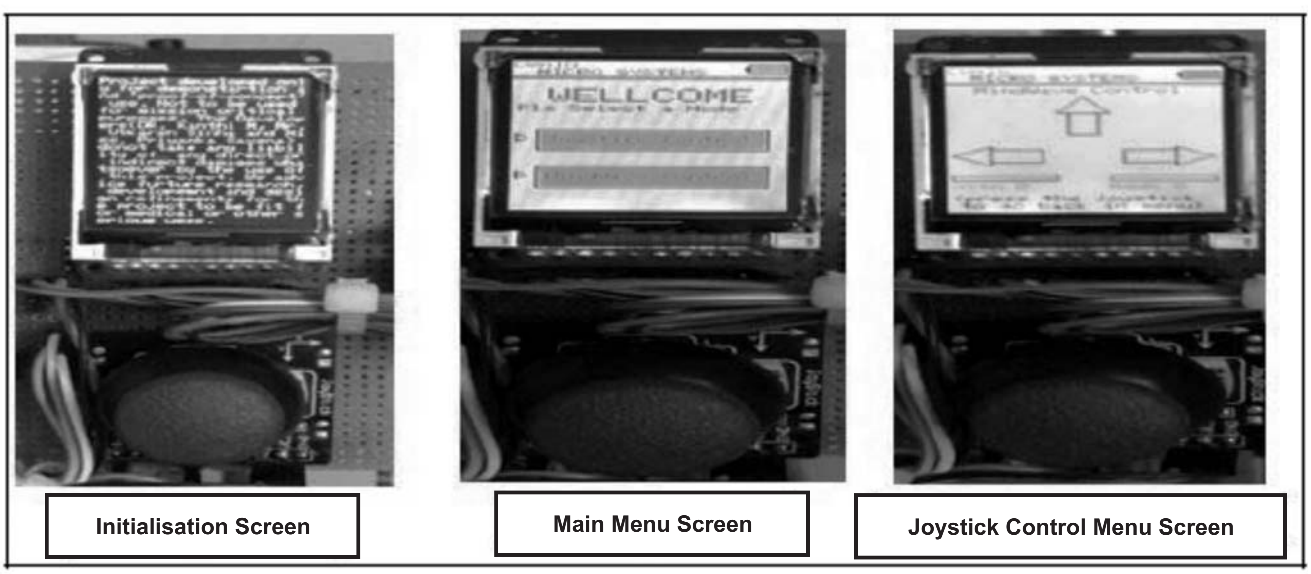


Figure 8: GUI on the wheelchir arm

A Neurosky Mind wave headset is used to pick up EEG signals from the brain. This is a commercialized version of the Open-EEG Project. The signal obtained from EEG sensor is processed by the microcontroller FRDM KL-25Z, a Freescale board. The microcontroller in return takes a decision for determining the direction of motion of wheelchair based on floor detection and obstacle avoidance sensors mounted on wheelchair's footplate. The MCU shows real time information on a colour LCD interfaced to it. Joystick control of the wheelchair is also provided as an additional interface option that can be chosen from the menu system of the project. The joystick and LCD is mounted on the wheelchair's armrest.

Figure 7 shows the graphical user interface used for wheelchair training results for forward, right and left movement respectively. It also shows the Attention and Meditation level of the subject wearing the Mind wave Dongle. The hardware GUI on the wheelchair's armrest is as given in Figure 8.Which is the actual snapshots of the LCD mounted on the wheelchair showing 'Directions', 'Attention Level', 'Battery Level' and menu based control of the modes of operation of wheelchair. The designed 'Mind Controlled Wheelchair' along with the Sensors, MCU and Embedeed GUI are shown in figure 9.

Figure 9: Mind controlled wheelchair with FRDM microcontroller and menu based embedded GUI

4. CONCLUSION

The project concludes into a functional Mind Controlled Wheelchair. Right, Left, Forward and Stop commands given by the disabled person are deciphered by embedded algorithms and suitably executed. By selecting suitable IC's and circuit design, cost effectiveness of overall project is optimized. The designed 'Mind Controlled Wheelchair' provides control of motion and direction of wheelchair by mind's attention and meditation level and eye blinks. The wheelchair avoids obstacles by using anobstacle detector, avoids tripping off edges by using a floor detector. The user is provided with an option to choose between control of wheelchair either by joystick or the headset depending upon the degree of disability of the user. A 'menu-based-embedded-GUI' facilitates this. The PC GUI made for training the user prior to using the actual wheelchair makes the 'Mind Controlled Wheelchair' an easy option to switch to.

The future work may include clinical testing on actual subjects, the firmware with few minor changes to make the system response better. The project has used a power supply as the motor consumes large power. Instead, a specific battery have to be used. This will allow an equation which will show the relationship between battery capacity and distance covered by the wheelchair.

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