Solar Powered Wheelchair for Physically Challenged People using Surface EMG Signal

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***Abstract*—This paper presents the design and implementation of low cost solar powered wheelchair for physically challenged people. The signals necessary to maneuver the wheelchair are acquired from different muscles of the hand using surface Electromyography (sEMG) technique. The raw sEMG signals collected from upper limb muscles are processed, characterized and classified. The direction of movement of wheelchair is extracted from the classified signal. The accuracy of the extracted EMG signals is found to be significantly high. A prototype is developed and tests verified the objective functionalities. The analysis of life cycle cost of the proposed wheelchair showed that the proposed wheelchair is financially feasible for developing countries.**

I. Introduction

Human-machine control (HMC) interfaces have found many useful applications, some of which could be used to aid physically challenged people [1-5]. In this work, we have proposed surface electromyographic (sEMG) signal controlled solar-powered wheelchair for people with limited limbic ability. If the person concerned exhibits some extent of muscular activation, the resulting EMG signal could be utilized to drive and navigate the wheelchair [6, 7]. As the sEMG signals are prone to noise contaminations from various external sources, they may not be adequate and appropriate for driving the wheelchair in some cases. Two design specifications are considered to mitigate this effects imposed by thus drawback: proper placement of stimulation electrodes with respect to recording electrodes and pre-processing of raw surface EMG signal to improve signal-to-noise ratio (SNR). A prototype is developed where real time EMG information is used to drive and navigate a solar powered wheelchair and tests yielded promising outcome. The tests performed with the proposed system yielded an average accuracy of 0.74. The development of the proposed system converges four different areas: EMG signal processing, power electronics, and control system design based on microcontroller.

The emergence of EMG signal is due to the rapid movement of ions across a cell membrane which creates a change in the ionic concentrations inside the cell with respect to outside. As a result, action potential develops which travels along the muscle fiber. An electric potential is generated due to the different concentration of ions on the different portions of the muscle. If a conductor is placed between any two of these points, an electrical current flows having very low amplitude. The action potentials are recorded by using sEMG technique. Weak signals produced by action potential require that sensitive electrodes be used in order to be detected. A sEMG sensor consists of two electrodes placed in orientation of its fibers on a muscle. Due to the diffusion of Na^+, K^+ and Cl^- ions, a difference in voltage is developed. In the relaxed state, axon holds most negative ions while the positive ions are held by the extra cellular environment. The membrane potential inside a nerve cell- while in its relaxed state is −90 mV. When a signal arrives through the axon, the local potential starts raising from −70 mV and as it reaches −50 mV, all positive ions enter the cell while the negative ions are forced out of the cell through the activation gates. Due to the exchange of ions, the local potential inside the cell reaches a peak of +35 mV. Staying at the peak for a minute duration, the cell returns to its relaxed state. This process repeats itself whenever an a signal arrives [8]. Every muscle cell has its own nerve cells that controls it. If more nerve cells are sending signals simultaneously, the muscle contracts harder which lead to stronger signals. Therefore the amplitude of the measured signal is proportional to the force of contraction of the muscle. sEMG sensors measure action potential between two electrodes on the skin with an extra electrode used for ground reference. The signal is first amplified using differential amplifier to reach within a certain range which could be recognized by any signal processing tools. The signal is then processed to generate necessary control signals which would later be used in the control system to control the wheelchair.

The objectives of this work are: to apply Root Mean Square (RMS) method for extracting real-time raw EMG signals from different surface EMG sensor positions [9], to make EMG signal compatible to be used with microcontroller which in turn will be able to navigate a wheelchair, and finally to design a low cost and maintenance free solar power battery.

II. Proposed Model

Fig. 1 shows the proposed solar powered wheelchair model. The main components are: Solar panel; Solar Charge controller and maximum power point tracker (MPPT); Battery bank; Microcontroller based motor driving circuit; Speed and direction controller and two DC motors.

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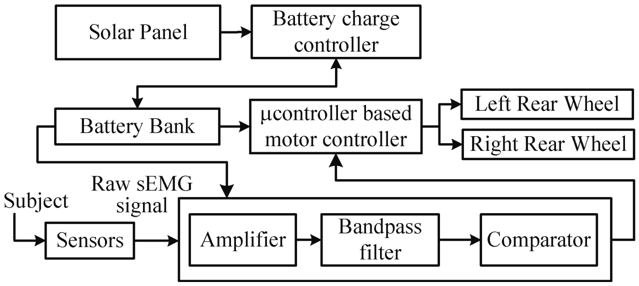

Fig. 1. Block diagram of the proposed system.

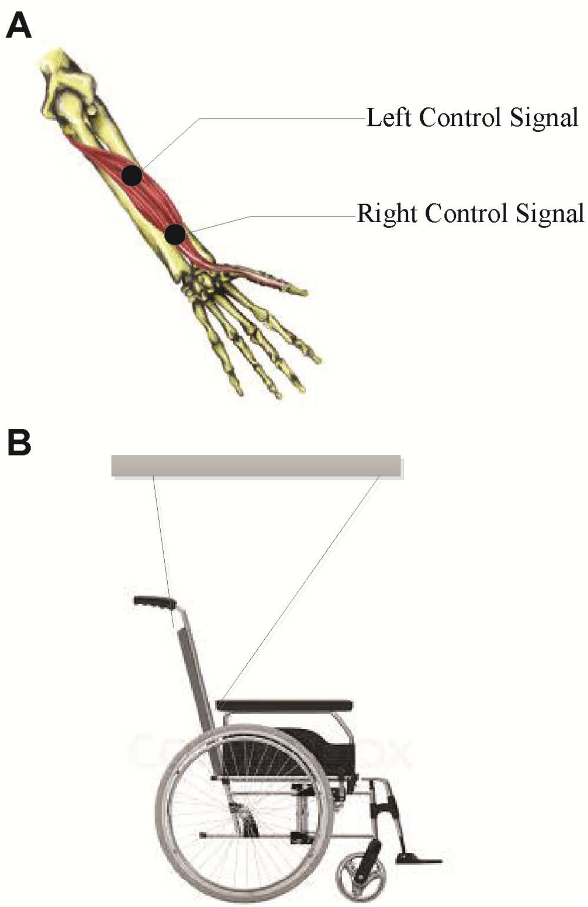

Fig. 2. Picture of the solar powered battery operated wheelchair. A The muscles from where the signals are acquired. B. The schamatic diagram of the wheenchair.

Solar panel converts solar radiation into electrical energy. Energy from sunlight is stored in the battery bank, which is controlled by a microcontroller based charge controller. The charge controller track the maximum power point (MPP). Lead acid battery is used because of its low cost, reliability, tolerance to overcharge, low initial impedance and the ability to deliver high current. Battery is needed as backup which is necessary as photo voltaic (PV) system only generates electricity when the sun is visible. Battery charge controller protects the batteries from overcharge and excessive discharge conditions. Microcontroller based motor driving circuit controls speed and direction of movement. Two 24 V, 5 A DC motors are used to drive the wheelchair. The motors are connected with a bevel gear arrangement which is finally connected with the axis of the wheel. Our proposed solar powered wheelchair is shown in Fig. 2.

A signal acquisition system is used to get the sEMG signal related to the movement of hand and forearm as shown in Fig. 3. The EMG signal is received by sEMG sensor. The acquired signals are pre-processed, filtered and amplified, and then fed to a microcontroller. The driving pulses are produced by the microcontroller, which in turn produces the necessary driving pulses for the motors to navigate the wheelchair. sEMG sensors of identical electrical characteristics are used to acquire muscular activation signals, denoted by V_{EMG}(raw). The frequency range of the surface EMG signals lies between 7 Hz to 500 Hz. Operating voltage required for a microcontroller is 0-5 V and hence comparator with adjustable gain amplifier converts the bipolar EMG into unipolar EMG signal, denoted by V_{EMG}. The circuit diagram for the signal preprocessing system is shown in Fig. 4.

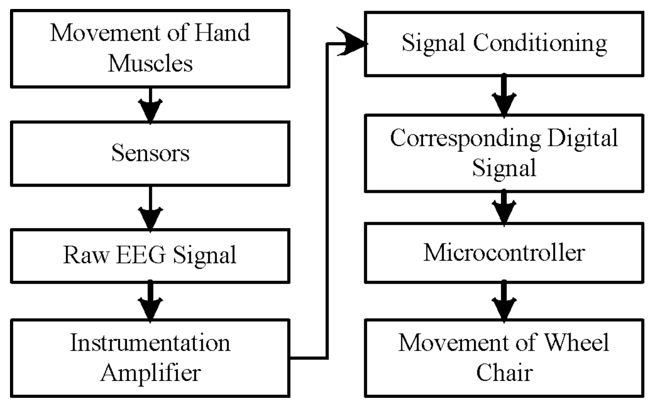

Fig. 3. Block diagram of the EMG signal processing to move wheelchair.

Fig. 5 shows the flow chart of the system firmware of the wheelchair which has been written in the microcontroller. Based on the received sEMG data, the wheelchair sends the digital signal to the motor of the wheelchair.

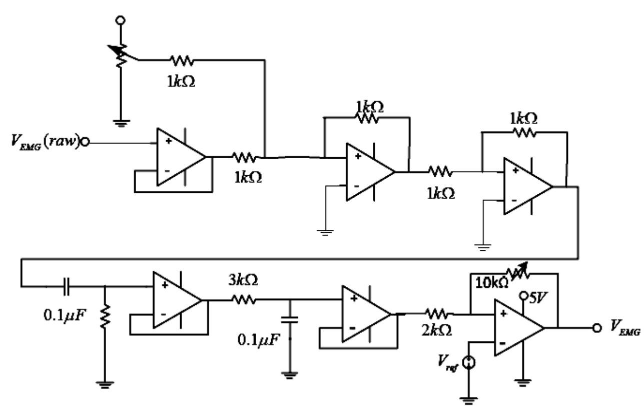

Fig. 4. Circuit diagram of sEMG signal processing.

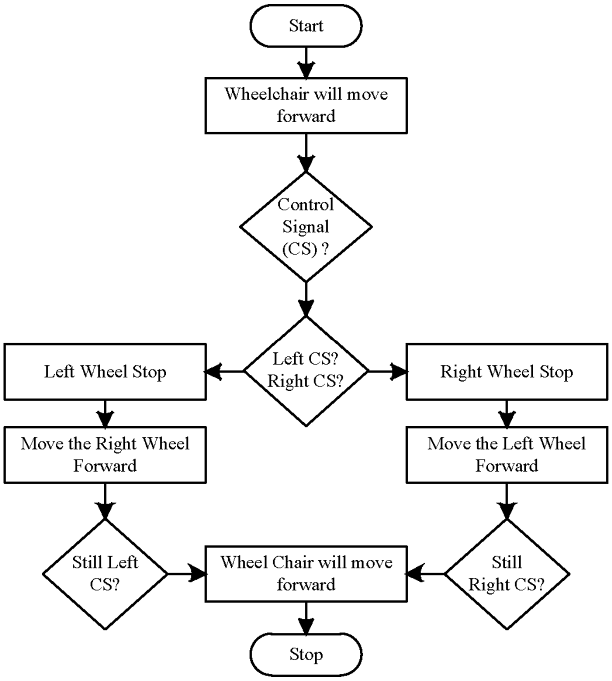

Fig. 5. Flow chart to navigare the wheelchair.

Fig. 6 shows wheelchair direction control circuit. Here D refers to diode (1N5400) and T refers to transistor (2SD1760/2SD1864). To move the wheelchair forward, both T_1 and T_2 will be switched ON. T_1 will switched ON and T_2 will switched OFF to move wheelchair rightward whereas T_1 will switched OFF and T_2 will switched ON to move wheelchair leftward. Here the diode D_1 and D_2 are used to discharge the residual current when motor is OFF.

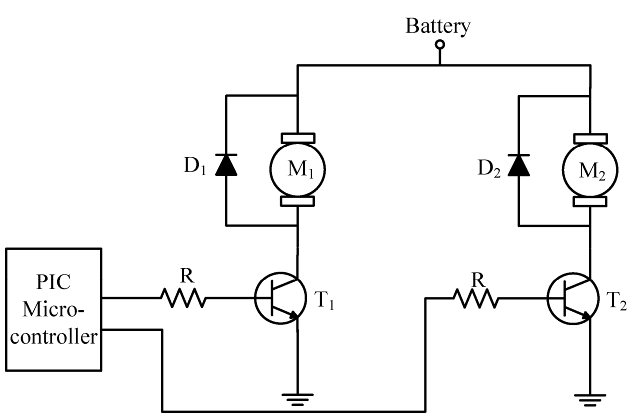

Fig. 6. Wheelchair direction control circuit.

III. sEMG Signal Extraction

Fig. 7 illustrates the successive stages in course of achieving RMS signals from raw EMG signals. The raw signal is filtered to remove any unwanted signal fragments within the signal. The filtered signal is rectified based on two facts:

i. The signal of the positive polarity contains sufficient information which are required to drive the motors

ii. The circuit needed to process unipolar signal is relatively less complex and easier to implement.

The rectified signal is smoothed using RC network to remove the ripples.

Table I shows movement of hand, sensor position on different muscles to extract sEMG signals and the corresponding functions to be performed by the wheelchair. The mean value of accuracy is found to be high.

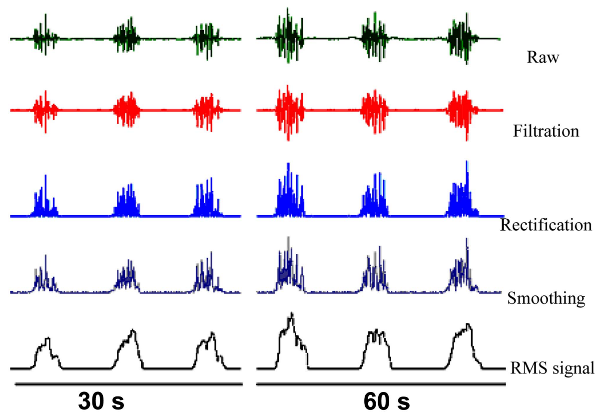

Fig. 7. Raw and RMS signal extracted from a sEMG sensor.

TABLE I. Movement of Hand and Muscle Activity and Detection Accuracy Rate

Motion	Active Muscles	Function	Accuracy
Wrist extension (WE)	Extensor carpi radialis longus, Extensor carpi radialis brevis, Extensor carpi ulnaris	Break	91%
Wrist flexion (WF)	Flexor carpi radialis, Flexor carpi ulnaris, Palmaris longus	Move forward	94%
Thumb	Extensor/Flexor Pollicis Longus,Extensor Pollicis Brevis, Abductor Pollicis Longus	Left/Right	94.1%
Finger(s) except thumb	Extensor/Flexor Digitorum Profundus, Extensor Carpi Ulnaris, Extensor Digitorum, Extensor Digiti Minimi	Left/Right	94.2%

IV. FINANCIAL ANALYSIS

For life cycle cost (LCC) analysis, we consider the following cases:

a) Case A –Driven by Human Hands: This is similar to the normal wheelchair which converts human labor of hands into mechanical energy. But it might not be suitable for one-sided paralyzed person.

b) Case B – With Battery Charged by National Grid: In this case, battery operated electric wheelchair is made with locally available materials, out of which the battery is charged by the national grid.

c) Case C – With Battery Charged by PV Array: In this case, battery operated electric wheelchair is made with battery bank which is charged by own array of PV panels-mounted on the wheelchair.

d) Case D – With Battery Charged by National Grid (No subsidy): In this case, battery operated electric wheel is made with locally available materials. The battery bank is charged by national grid and Government is not paying subsidy.

e) Case E – With Battery Charged Wheelchair by National Grid (commercially available): In this case, commercially available battery operated electric wheelchair is bought from market. The battery bank provided with the device is charged by the national grid.

Each of these cases are evaluated in terms of various parameters and entities. Table II shows the unit price of energy and LCC cost analysis for different cases.

TABLE II. LCC ANALYSIS

Motion	Case A	Case B	Case C	Case D	Case E
Wheelchair	6,000	6,000	6,000	6,000	10,0000
PVA	0	0	7,200	0	0
Battery	0	21,000	21,000	21,000	21,000
Converter	0	5,000	6,000	5,000	5,000
Ins. C	0	2,000	3,000	2,000	2,000
Capital Cost	6,000	34,000	43,200	34,000	128,000
Elect. Cost	0	9,636	0	26,980	26,980
O and M Cost	780	3,000	6,000	3,000	3,000
NRC	500	25,000	25,000	25,000	25,000
Total LCC	7,280	71,636	74,200	88,980	182,980
Total Energy	0	38,544	38,544	38,544	38,544
Unit cost	0	1.86	1.93	2.31	4.75

Legend: PVA: PV Array; Ins. C: Installation Cost; Elect. Cost: Electricity Cost; NRC: Non-recurring cost;

V. CONCLUSION

Assistive device for physically challenged people is a critical need which intends to ease their everyday lives. The design of a low cost solar powered wheelchair for physically challenged people is proposed and implemented. The design is carried out using parts that are low cost and also readily available at any local market. The navigation of the wheelchair is controlled by surface EMG signals which are collected from the upper limbic portion of the user. The control functions of the implemented prototype are tested against desired behavior and the accuracy is found to be satisfactory. The Life cycle cost of the solar powered wheelchair is analyzed and presented to determine the feasibility of such a system. The analysis demonstrates that the system is economically practical.

VI. REFERENCES

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