

A salutary biotechnical approach for explosive identification and border patrol using electrophysiological signals

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Abstract

This paper visualizes a salutary approach to maneuver and implement a successful sensor embedded rover that could be used for the surveillance of harmful components like bombs and underground mines that usually contain embedded metallic shrapnel and avoid detonation owing to its light frame. In case of any hostile situation, rescue operations are performed by human and trained dogs in a very precarious pandemonium risking the chances of victimizing themselves. Therefore, to enhance the safety and celerity¹ of any defensive op, the rover is controlled directly through bio-electrical signals which are spontaneous in decision making, tweaking their application by using the variations in Electroencephalographic (EEG) and Electrooculographic (EOG) readings in the blink of an eye. Subsequently, the raw mindwave-sensor data is imported into MATLAB, thru the NeuroSky Headset RF receiver, these values are interpreted to normalized ranges so that 4 directions or degrees of freedom shall be implemented, thus opening up possibilities of handsfree-operation. The rover includes Passive-Infrared sensors (PIR) which are used for detecting human presence, motion/mobility and for detecting the illegal entry of intruders across any defensive line. The ATmega 328P microcontroller onboard the Arduino is used to control the sensors on board the while the ZigBee modules are used for ultra-low voltage transmitting and receiving sensor data. Furthermore, an ultrasonic sensor to analyze terrain and measure the distance from impending intrusions vastly improves the rover's mobility on challenging terrains.

Keywords: *Electroencephalographic, electrooculographic, celerity.*

1. Introduction

Considering all advance that was once regarded fanciful, the immense advances in biomedical instrumentation, human electrophysiological signals now are utilized as a part of various applications instead of a medical diagnosis. Cases of these bioelectrical signals incorporate Electro-Encephalo-Gram, Phono-Cardio-Gram, Electro-Cardio-Gram, and Electro-Oculo-Gram. Bio-Electrical Signals have been being used to upgrade lives of generally empowered individuals up to this point [X, Y, Z]. One of the latest non-restorative application for these bio-electrical signals is biometric verification [1], [2],[3]. However, our project stems from a humble inspiration from an unexpected mishapresulting in the ambush and mutilation of 2 of our soldiers. This, infact, is all the more reason that bio-technological instrumentation can be exceedingly salutary where there is a life on the line. This paper introduces a novel technique to maneuver sensor-embedded rovers that are accoutered forenhancement of border security and patrol. It is proposed that spectral brainwave frequencies be normalized to ranges using extensive mathematical and computational signal processing techniques and high-level feature extraction along with classification with open-source toolboxes, we arrive at a juncture where the ranges are assigned degrees of freedom or direction so as to maneuver the intended rover with deft celerity. As defined by Jesper Rønager, a master neurologist, in [8], the brain is made of around 100 billion neurons. Each individual has particular complex neural wiring in the cerebral cortex. The EEG signals travel through this astounding wiring of neurons making it exceptional in connection with one subject to another. Along these lines, in this paper, a preliminary report is passed on to inspect the discriminative limit

of the range of cerebrum waves acquired from crude EEG information signals on a database of 25 subjects. The layout of this paper is sorted out as takes after. Section II shows a writing survey of the beforehand proposed calculations characterization and extraction of brainwaves. Section III portrays in points of interest the proposed EEG controlled sensor implanted meanderer. The accomplished outcomes are exhibited in Section IV. Eventually, Section V condenses the principle conclusions and future degree.

2. Literature review

Although the thought of bio-electrical signals to operate programmable integrated technology for real-time purposes was mentioned earlier in [1], [2] and [3] yet they were but medical applications targeted for a smaller demographic, according to the authors' knowledge. While innovative and sagacious ideas of pre-processing, classification and feature extraction have been previously proposed [6,7], all such implementations were separate and never combined to implement a working sensor-embedded rover for defense purposes. Furthermore, the classification of distinctive spectral ranges of brain waves has been achieved through software previously, they are propriety and not open source according to the authors' knowledge. [9]. It is understood that the Combination of sensors used here are but a reflection of a number of other systems but not implemented or controlled by electrophysiological signals for our defined purposes. [10]

3. Proposed system

The implementation perused in this dissertation involves two primary modules; Brain Computing Interface which include data acquisition, pre-processing, feature extraction and classification. The other module involves a sensor-embedded rover that includes Neurosky Mindwave Headset, Sensors, IoT



Fig. 1: Proposed system blueprint

Brain computer interface

A. Data acquisition

All Electrophysiological signals examined in this paper were recorded utilizing NeuroskyMindwave headset which comprises of an ear holding clip and a sensor arm. This headset is really utilized for recording Electro-Encephalo-Gram signals; in any case, it can be utilized to gauge Electro-Oculo-Gram signals as the arm sensor is laying on the temple over the left eye (Fp1 position) and reference electrode is on the ear holding clip (X1 position) which represents the approaching artifacts (unwanted frequencies that meddle with brainwaves). The headset itself is accoutered with dry electrodes which do not require further application of conductive pastes nor any intrusive methods. Therefore, it takes not as much as a large portion of a moment to mount the headset and begin recording signals. Likewise, the headset isn't wired which makes it well suited for useful usage of a sans hands task. It works at an inspecting recurrence of 512 Hz. The crude flag was gathered from 25 solid, calm subjects. The volunteers didn't encounter any weariness amid recording sessions. In one session, 10-15 trials were recorded with a span of 2 minutes each. Each volunteer was requested to make the regular eye motions in every trial. The volunteer was asked for to minimize baseless eye developments however much as could reasonably be expected. The crude signals from 15 subjects were recorded in one session without more than 2 minutes of successive testing time per person. The chronicle condition was tranquil, ordinary temperature, and daylight. The figure above demonstrates the recorded eye flickering sign utilizing Neurosky headset. MATLAB programming was utilized for recording the crude flag from Neurosky headset and further handling. In the following sub-area, the algorithmic stratagems to control crude EEG information to remove different otherworldly frequencies of cerebrum waves are talked about.

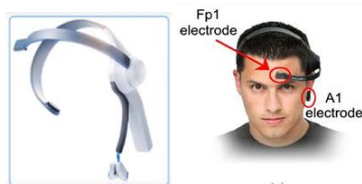


Fig. 2: (a) NeuroskyMindwave Headset (b) Mounted Headset Electrode Description

B. Pre-Processing

The underlying advance incorporates the accompanying capacities joined by parameters recorded as takes after: "libisloaded" with the parameter 'Thinkgear' will returns true on the off chance that the ThinkGear library is stacked, and false if not. "loadlibrary" with the parameters with 'Thinkgear.dll','thinkgear.h' loads the limits portrayed in the header record and found in the library. By and by, the capacity "calllib" can call a capacity in the ThinkGear library. "calllib" with the parameters 'Thinkgear', 'TG Get Driver

Version' straightforwardly restores the form of the stacked library. In the consequent stage, the capacity "calllib" with the parameters 'Thinkgear', 'TG Get New Connection Id' gets another affiliation ID handle to ThinkGear. The esteem '- 1' returns if an over the top number of affiliations have been made. The affiliation is set up by using the going with command: 'calllib' with the parameters 'Thinkgear', 'TG Connect', Id, Com Port Name, TG BAUD 115200. In the resulting stage, we tried to scrutinize a bundle of information from the affiliation. We use the "TG Read Packets" work with ID parameter and number of parcels to examine. The summoning of the capacity "calllib" with the parameters 'Thinkgear', 'TG_ReadPackets' Id, connectionID = 1 returns false for any inconsistency happened, and by and large obvious. The limit TG_GetValueStatus() checks if an esteem has been revived by TG_ReadPackets(). If this limit returns true, we can use TG_GetValue() to get the revived estimation of the foul Electro-Encephalo-Gram signals. Along these lines, we can read the estimation of grungy EEG motion with the most distant recurrence of 512 Hz. Examining recurrence is determined to 512 Hz, and we control time delays in inspecting. The estimation of the banner and time are made out of the grouped data. A one-minute trial of the Electro-Encephalo-Gram banner is displayed in figure 3. In this paper, A Fast Fourier Transform (FFT) is used as a capable computation to enlist the DFT and its regressive execution (IFFT to figure IDFT) [1, 2]. Computational multifaceted nature is $O(N^2)$ for standard DFT and $N(\log N)$ for FFT procedure. FFT computation relies upon Divide and Conquer Algorithm. It isolates the change of size X to change the size X1 and X2. In this paper, the FFT calculation is utilizing for the extent of the example, as indicated by recipe (12): $N/2^k$, where k is a natural number. The FFT and IFFT calculations are executed in the MATLAB environment. Two of the most critical data values are found in function fft (data, X). Information is a vector of flag and X is a size of the change. In the event that X is not as much as the length of Data, the grouping l is truncated. In the event that X is more noteworthy than the length of presentData, vector l is cushioned with trailing in zeros to length X. This function restores the DFT of vector x, registered with the FFT calculation. Function ifft(Data, N) works in the same way, but returns values from a time.

C. Feature extraction stage

The objective of highlight extraction is to discover a change that transforms the original signal into a generally low dimensional feature space that can protect the discriminative data of each subject. Four gatherings of waves (Alpha, Beta, Gamma, Theta) need to be extracted from raw EEG data using themathematical pre-processing implemented thru MATLAB to successfully engage all four degrees/directions of freedom. While there are quite innovative and handy software tools like EEGLAB which is an open source implementation by the Centre for Neuroscience Research in the University of California, San Diego. [3] Furthermore, open source toolboxes to extract discrete brain wave frequencies are available on GitHub, the reliability and compatibility of our method with the Neurosky Mindwave Mobile was too lucrative to pass upon as the data was consistent with previous researches in the Neuroscience on Neurofeedback and other booming neuro-technical tools. Thus, the spectral ranges allow for us to try and match each range with a distinctive direction of motion so as to avoid overlap in maneuvering the rover. The highlights extricated in this paper was propelled by the highlights utilized in [6], be that as it may, they are dealt with in an alternate way. The amplitude and precision include in [6] characterize the distinction in abundance amongst saccade and recreation. In any case, top adequacy highlights separated in this paper characterize the quality of the flickering activity. Also, the quality of the flickering activity is characterized by different highlights including vitality, territory, and mean of positive and negative redirections. The main subordinate-based highlights in this letter are utilized to characterize the speed of the flickering

activity as in [6]. Extra highlights are separated to characterize speed and increasing the speed of the flickering activity in view of incline, span, and second subordinate of the squinting waveform. Each gathering of highlights was tried and contrasted with the proposed framework, at that point, the gatherings were connected together to explore the impact of a link on framework's execution. This is talked about in subtle elements in Section IV-A.

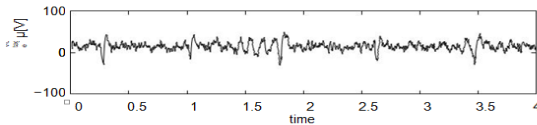


Fig. 3: Raw EEG Signal

Table 1: List of the Spectral Brainwave Frequencies

NAME OF THE WAVE	FREQUENCY (Hz)	TYPICAL AMPLITUDE
DELTA	0.1-4	100-200
THETA	4-8	HIGHER THAN 30
ALPHA	8-13	30-50 or HIGHER
BETA	13-30	2-20 or HIGHER
GAMMA	40-60	3-5 or HIGHER

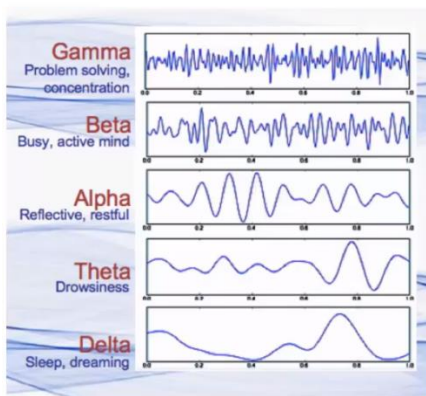


Fig. 4: Distinctive brainwave spectral frequencies and their characteristics with generic signal waveform

D. Classification stage

Power Spectral Density is the champion among the essential instrument for advanced digital signal processing (DSP). It urges us to know how the nature of a signal is dispersed in the recurrence space and its unit is vitality per recurrence. Power Spectral Density gives the quality of the distinctive energies of a signal as a component of recurrence. Subsequently, this gives us an idea about the strength of frequencies ranging from strong to feeble. So ascertaining energy inside a particular recurrence scale is conceivable by fusing Power Spectral Density inside that recurrence scale. Power Spectral Density for a finite control signal $x(t)$ in operational terms can be described as passing the signal $x(t)$ through a flawless narrowband filter with trade fill in as Eqn 1 [5]. The Power Spectral Density evaluated at f_0 would now have the capacity to be defined to be the ponder control at the channel yield, disengaged by the filter width Δf in the purpose of confinement as $\Delta f \rightarrow 0$ [5]. Fast Fourier Transform (FFT) is a greatly steady instrument for the count of Power Spectral Density. MATLAB with the expansion to EEGLAB can be used for the count of Power Spectral Density. By virtue of EEG signal, we understand that this signal is nonstationary wave signal, in any case, examination of this signal for under 12 seconds can be normal as a stationary wave signal [4]. Thus in this dissertation, we have used 10sec of Electro-Encephalo-Gramwave signal for applying Power Spectral Density. EEG LAB usage of the above Power Spectral Density is as per the following.

```
spectra, freqs equals spec topo(EEG.data(2,:,:), 0, EEG.srate
//theta=4to8,beta=13to30,delta=1to4,gamma=30to80,
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alpha=8to13
find
freqs>1 and freqs<4 equals deltaIdx
find
freqs>4 and freqs<8 equals thetaIdx
find
freqs>8 and freqs<13 equals alphaIdx
find
freqs>13 and freqs<30 equals betaIdx
find
freqs>30 and freqs<80 equals gammaIdx
//mean of 10.^(spectra(deltaIdx)/10) equals compute absolute
powerdeltaPower
Mean of 10.^(spectra(thetaIdx)/10) equals thetaPower
Mean of 10.^(spectra(alphaIdx)/10) equals alphaPower
Mean of 10.^(spectra(betaIdx)/10) equals betaPower
Mean of 10.^(spectra(gammaIdx)/10) equals gammaPower
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Sensor-embedded rover

A. Neurosky

Neurosky is a brainwave computing technology which helps in measuring EEG and EOG by using the Sense propriety algorithms for meditation and attention level, we record the calmness or relaxation and focus or attention of the subject, which will be ranging from 0 to 100. this will help us determine the subject status of mind while giving the commands needed for the rover.

B. Internet of things (IoT)

Arduino: a computer hardware which is an open source and reliable to use it in the sensor embedded rover. This microcontroller chip helps rover understand the instructions given by the user, through the rs232 module.

Relay Motors: This electrically operated switch will help the rover move from one direction to another by controlling the motors on the shells, by switching the power to different motors and move the rover, instruction to the relay motor are given by the Arduino.

Zig Bee Transmitter and Receiver (RS232): Data transmission will be interfaced between the Zigbee connected to the PC and Zigbee embedded on the rover. This RS232 module has a 15meter range by which the user will transmit his instructions to the rover.

C. Sensors

Passive Infrared Sensor (PIR): Passive Infrared Sensor was used to detect any motion that is happening in front of the rover and will send the feedback to the user, for example if a person passes through the sensor, sensor will detect the change in heat levels from room temperature and gives the feedback to the user.

Ultrasonic : It is a distance measuring sensor, which sends sound waves and determine the distance between the object and the rover. it also guides us by helping in identifying the terrains in front of the rover.

Metal Detector: Metal detector is embedded on the rover which gives the feedback about any metal detected in the rover area. This helps in detecting any sort of land mines which are underground.

4. Performance evaluation and results

The empirical setup of proposed system is divided into different phases; user-adaptation and user-tryout.

User-adaptation

The brain activity of an individual is monitored and recorded with the same parameters as prescribed earlier in this paper through the Meditation App in Neurosky Mindwave Starter Kit Software. It is

realized that while the setup is operational with no further modifications in almost all cases, it would be best to have a reference point in the form of data from the individual's brain activity. Therefore, in case any synchronization tribulations, the system can be tweaked to suit the user as required at the time of empirical implementation.

User-tryout

The complete setup includes the user wearing the Neurosky Headpiece with the RF receiver at the computer end, the sensor-embedded rover connected via Zigbee Transmitter and Receiver at the portable computer end. Once the headset is mounted, the user will be provided a feedback of his online brainwaves in the form of a graph. With respect to the graph and prior debriefing of the spectrum of brainwaves, the user can adapt accordingly to maneuver the rover in the theorized 4 degrees of freedom or directions enlisted in this paper.

5. Document and future scope

In this dissertation, a salutary proposition for maneuvering a sensor-embedded defense rover was proposed using distinctive spectrum of brainwaves from raw EEG signals. Using four normalized ranges of frequencies corresponding to distinctive spectrums in brainwaves, namely, Alpha, Beta, Gamma and Delta that were assigned to 4 directions of movement with respect to the rover, were obtained over a database of 25 subjects. With the help of open-source toolboxes like EEGLAB, achieving classified mean values of brainwave frequencies was possible through implementation of Power Spectral Density (PSD) which in turn is computed with using Fast Fourier Transform (FFT) that have designated functions of use in MATLAB and EEGLAB. Notwithstanding the fact that the work done here elucidates the scope to use bio-electrical signals extracted from raw EEG recordings, the database used has a diminutive sample (20 subjects only). Therefore, it is in the Best interest of development that a larger dataset or sample size be perused and empirically tested. Also, different feature extraction and classification techniques can be tested. Instead of testing and acquiring data through the Neurosky Headset, a much more advanced headset with more number of sensors fitted to perhaps monitor an expansive area across the whole brain, thus opening up opportunities to control the sensor-embedded rover with improved precision and accuracy. It is to be noted that the proposed system, although salutary to the defense forces, is an initial proposal and it is evident that it shall not be implemented right away when there are lives on the line as the accuracy and reliability of the movement of the rover is restricted due to using the dry-electrode Neurosky Headset setup against clinical devices which might be invasive or wet-electrode attachments with a higher number of advanced sensors that detect much more than just EEG and EOG signals. Furthermore, In times to come a study should be carried to show how Exhaustion, Medications, alcohol, and maturity affect the performance of the system. As the Neurosky Mindwave headset can note both Electro-Encephalo-Gram and Electro-Oculo-Gram signals, it can be utilized to add biometric authentication functionality to the already developed system that this paper proposes. This would enable the system to be locked to user authentication, thus providing enhanced security to defense forces and a fool-proof system in case the device falls in the wrong hands, compromising the rectitude of our efforts.

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