Brain Controlled Unmanned Ariel Vehicle

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Abstract: Brain Computer interfacing (BCI) is an innovation that is just about four decades old and it was created exclusively to develop and improving the effect of neuro prosthetics. In any case, in the ongoing occasions, with the commercialization of non-intrusive electroencephalogram (EEG) headsets, the innovation has seen a wide assortment of uses like home automation, wheelchair control, vehicle directing and so forth. One of the most recent created applications is the mind-controlled quadrotor unmanned aerial vehicle. These applications, how-ever, don't require a rapid reaction and give agreeable outcomes when standard grouping techniques like Support Vector Machine (SVM) and Multi-Layer Perceptron (MLPC). Issues are confronted when there is a prerequisite for rapid control on account of settled wing unmanned flying vehicles where such strategies are rendered problematic because of the low speed of characterization. Such an application requires the framework to group information at high speeds with the end goal to hold the controllability of the vehicle. This paper proposes a novel strategy for grouping which utilizes a blend of Basic Spatial Worldview and Straight Discriminant Examination that gives an enhanced characterization precision continuously. A non-straight SVM based grouping strategy has likewise been talked about. Further, this paper examines the usage of the proposed strategy on a settled wing and VTOL unmanned aeronautical vehicles.

Keywords: *UAV, Brain, Unmanned Aerial Vehicle, Brain Computer Interfacing*

1. Introduction

Research in neurological investigations hit a barrier when the need emerged to comprehend mind waves. The multifaceted nature of such waves must be examined utilizing progressed computational apparatuses. Cerebrum PC Interfaces (BCIs) or Mind-Machine Interfaces (MMI) were conceived out of the need to catch and break down the signs on PCs. BCI is a counterfeit framework that consolidates the correspondence between the mind and an outer gadget or a PC. [1] [2]. In this framework the movement of the cerebrum amid a specific activity is taken advantage of utilizing electroencephalogram (EEG) gadgets which are sent to focal framework to be prepared and separate them into control signals, at first conceived for restoration to enable individuals to recover engine abilities that are lost or missing currently guarantees another field of research for both medicinal and Designing applications. The primary research on BCIs occurred in 1970 at College of California at Los Angeles which was gone for assessing the capacity of BCI to support neuroprosthetics [3][4].

BCI increased further footing when it was utilized to treat secured disorders and neuromuscular separations. Sound related, visual and facial muscles regularly lose the unwavering quality and are regularly depleted when in successive or drawn out utilize [1]. Each idea or activity offers ascend to a specific electrical action. A condition of wandering off in fantasy land or profound reflection discharges delta waves (0-3 Hz). Resting emanates theta waves (3-7 Hz). A condition of cognizance discharges alpha waves (8-12 Hz). Commitment in a specific movement or critical thinking produces beta waves (12-38 Hz) [5] [12]. An EEG utilizes this recurrence area highlight to show the clients goal regarding cerebrum waves onto an outer gadget to screen and control an outside gadget. The simple first of BCI frameworks were the P300 spellers which could peruse the cerebrum flags and perused letters for correspondence between the patients who were physically tested [4]. California medicinal focus concocted cerebrum controlled prosthetic legs with helping the patients with spinal rope wounds walk. The framework could be utilized by the patient to move the prosthetic progressively [5]. A comparable framework was produced in Washington to reestablish the hands for the general population with neural disengagement [6]. A BCI-controlled wheelchair was created for the patients who couldn't utilize the joystick or the equivalent. Distinctive models of the wheelchair were created relying upon the measure of control left to the client's attentiveness. [7] The extent of research of BCI was at first bound to just medicinal applications for recognition of various cerebrum states, for example, readiness, feeling, and consideration; be that as it may, it has now stretched out to incorporate designing and mechanical applications too. In a paper proposed by Bastian Venthuret. al, the focus dimension of an administrator in a manufacturing plant was analyzed over some stretch of time. They arranged a model that

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would get to the reaction time of an administrator to the distinctive dimensions of ready messages. This would serve supportive in maintaining a strategic distance from mishaps that could some way or another happen because of low sharpness or exhaustion [8]. The presentation of BCIs in the field of home robotization has been investigated by Wei Tuck Lee, et al, wherein they have arranged a virtual home condition in which an individual can control machines specifically with the brain [9]. Cerebrum PC Interface is additionally discovered advancing itself into the field of Aviation design, there have been fruitful endeavors made to control a multi-rotor unmanned ethereal vehicle (UAV) utilizing BCI. An effective model has been produced wherein a quadcopter is made to maneuverer upward, descending, right and left headings relying upon the direction gotten by the pilots mind signals [10]. In another fruitful endeavor by Vijayendraet. al. [18], the creators have exhibited 95% exactness in mind PC interface based control of UAVs, with the exchange off among precision and constant usage. The proposed methodology is extremely effective yet has restricted rate of 25 Hz. In addition, there has been no endeavor so far to control a settled wing UAV because of the unpredictability of gushing of information at a high rate and their consequent characterization of the EEG flags that is essential for fast UAV control. This paper intends to unravel the complexities engaged with the execution of a BCI controlled settled wing flying machine. The primary commitment of this paper is structuring the control system for moving a delta-winged UAV utilizing Normal Spatial Worldview (CSP) and Straight Discriminant Examination (LDA) of the EEG signs and its usage. These strategies, with information handling rate of around 97 Hertz, give a fast grouping stage to setting up a steady control connect to the UAV and furthermore accomplish an abnormal state of characterization exactness of 85%.

2. Methodology

2.1 Experimental Subjects

There were a sum of 14 subjects engaged with this experimental think about, out of which 5 were female and 9 male subjects, all matured between 18-24 years. The Chosen Subjects did not have any related knowledge in any BCI/HMI related undertakings and a composed assent of their investment in the examination was submitted to the moral board of trustees of Indian Foundation of Science.

2.2 Acquisition Protocol

A convention was characterized and pursued for procurement of EEG information from the subjects. The convention directs four engine symbolism undertaking be performed with rest breaks consolidated in the middle of every assignment. This guarantees the engine symbolism undertakings are strengthened and the maintenance of data in the flag is adequate. Fig.1 imagines the convention pursued for information procurement.

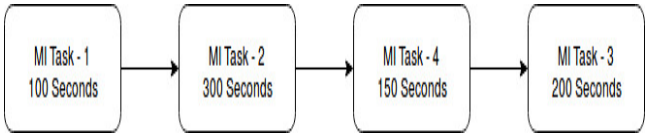

Figure.1. Workflow of MI Tasks

The Motor Imagery (MI) Procurement method is part into four assignments. Errand 1 includes imagining left-hand movement with no physical development. Assignment 2 is the equivalent as Errand 1 yet is performed with the right-hand. Assignment 3 requires the subject to picture left-hand development alongside the development of fingers and elbow. Errand 4 imitates Assignment 3 yet is performed with the right-hand. The EEG information procured amid these 4 errands is delineated in Fig. 2. The varieties in the EEG information are outwardly discernable and the exactness with which the highlights can be removed is exclusively relied upon the calculation utilized.

Finger and elbow developments are utilized to build the number of actuations in the tangible engine cortex. Time interims in which the assignments are performed were kept arrhythmic with the goal that the plenty fullness of enactments are safeguarded which generally will in general disappear out when playing out a monotonous activity.

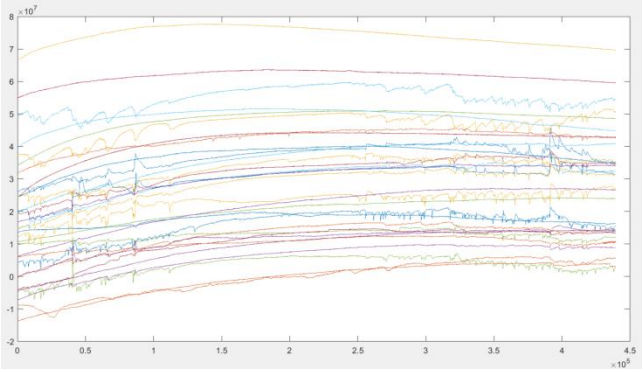

Figure.2. MI tasks for Acquisition

2.3 Subject Training

Centered idea is basic to plan a BCI arrangement of essential precision as diffused point of view prompts commotion in the obtained information. The preparation of the subjects in this test were performed with the help of a gear-tooth nitive suite called the Xavier Control Board ,which comes packaged with the Emotiv SDK. The subjects train to center around the developments of a virtual box

under insignificant tangible diversions to empower productive MI errand execution.

2.4 EEG and Brain Data

The brain activity is recorded with the assistance of a commercially available EEG headset, called EPOC+ by EmotivInc. (Fig.3) which provides 14-channel EEG data.

Figure.3: EPOC+Headset(14-channel)

The EEG bands in the human brain activity are usually classified as:

- **Delta**-Delta band a frequency of3 Hz or below. It tends to be the highest in amplitude and the slowest waves.
- **Theta**-This band has a frequency of 3.5 to 7.5 Hz and is classified as 'slow' activity.
- **Alpha**- This region is localized between 7.5 and 13 Hz and is usually best seen in the posterior region soft he head on each side.
- **Beta** - Beta activity is 'fast' activity and has frequency of 14 Hz and greater.
- **Gamma** - A gamma signal is a pattern of neural oscillation in humans with a frequency between 25 and 100 Hz, though 40 Hz is typical.

2.5 Algorithm

As talked about in the past areas, in this investigation we have utilized a mix of normal spatial worldview (CSP) for highlight extraction and direct discriminant examination (LDA) for model preparing. The calculation definitions and fitting graphical investigation are talked about in this segment.

1) Common Spatial Paradigm (CSP): CSP algorithm disintegrates the signal into additive components so that they have maximal variance difference in two windows. EEG signals are usually formalized as:

$$\{E_n\}^N \in R^{ch\times time} \quad (1)$$

The scope of time preliminaries shifted from 100 to 300 seconds.

Presently, to apply EEG signals for characterization, we should change them first. The change to an element vector happens as pursue:

$$E_n \in R^{ch\times time} \longrightarrow x_n \in R^d \quad (2)$$

Major points of concern here are:

- Noise reduction has to be done
- Frequency band selector for optimal performance
- Channel Selection

Feature matrix that could be obtained as:

$$X \in R^{d\times N} \quad (3)$$

The purpose of using a spatial filterlike CSP, in this study, is that the signals provided by the algorithm are easier to classify even with simple methods. The objective of this section is to design spatial filters that result in optimal variances for the classification of two motor imagery signals related to left and right a movements. The CSP filter (by Muller-Gerkingetal.) is mathematically written as:

$$S=W^TE \quad (4)$$

Where, $W \in R^{d\times ch}$ is a spatial filter matrix and $S \in R^{d\times time}$ is the filtered signal matrix. The fundamental of CSP is to maximize Eq.5:

$$trW^T\Sigma_1W \quad (5)$$

With subject to Eq. 6

$$W^T(\Sigma_1+\Sigma_2)W=I \quad (6)$$

Where,

$$\Sigma_1 = Exp\ \frac{EnEn^T}{trEnEn^T}\ \ En \in \{class1\} \quad (7)$$

$$\Sigma_2 = Exp\ \frac{EnEn^T}{trEnEn^T}\ \ En \in \{class2\} \quad (8)$$

Above equations solved with the help of generalized eigen value problem. Initially, we decompose as:

$$\Sigma_1+\Sigma_2 = UDU^T \quad (9)$$

where, V is a collection of eigen vectors, and Λ is a diagonal matrix of eigen values. Next we try to find the value of $P=D^{-1}U^T$, and

$$\hat{\Sigma}_1=P\Sigma_1P^T \quad (10)$$

$$\hat{\Sigma}_2 = P\Sigma_2 P^T \quad (11)$$

Now, any ortho-normal matrices V satisfy the condition $V^T(\hat{\Sigma}_1+\hat{\Sigma}_2)V=I$

2

Finally, we disintegrate as:

$$\hat{\Sigma}_1 = V\Lambda V^T \quad (12)$$

where, Visa collection of eigen vectors, and Λ is a diagonal matrix of eigen values. The CSP filter set is obtained as:

$$W = P^T V \quad (13)$$

The descriptions would be:

$$W^T\Sigma_1 W = \Lambda = \begin{bmatrix} \lambda_1 & & \\ & \ddots & \\ & & \lambda_{ch} \end{bmatrix} \quad (14)$$

$$W^T\Sigma_2 W = I - \Lambda = \begin{bmatrix} 1-\lambda_1 & & \\ & \ddots & \\ & & 1-\lambda_{ch} \end{bmatrix} \quad (15)$$

Where $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_{ch}$. Hence, the first CSP filter **ω** provides maximal variance for 1st class, and the last filter ω_2 for 2nd class. The first and last m filters are selected in the following manner:

$$W_{csp} = (\omega_1 \cdots \omega_m \omega_{ch-m+1} \cdots \omega_{ch}) \in R^{2m \times ch} \quad (16)$$

And the filtered signal mathematically is:

$$_{cs}s(t) = W^T e(t) = (s_1(t) \quad \cdots \quad s_d(t))^T, \quad (17)$$

i.e d=2m

Feature vector=$(x_1,x_1,\ldots,x_d)^T$,is then calculated as:

$$X_i = \log \frac{var\,[s_{i(t)}]}{\sum_{i=1}^{d} var\,[s_{i(t)}]} \quad (18)$$

Here our feature space constructed, now we go ahead by training the model using LDA.

2.6 Linear Discriminant Analysis

Fisher's direct discriminat investigation (LDA), an exceptionally famous twofold classifier, depends on mean vectors and covariance frameworks of examples of every individual class. Here, we endeavor to change over a d-dimensional vector x to a scalar z as:

$$z = w^T x \quad (19)$$

Essentially, the LDA furnishes us with an ideal projection w so z turns out to be anything but difficult to segregate. The major of LDA (standard) is boosting:

$$J(w) = \frac{m1\_m2}{s1_+s2} \quad (20)$$

where,

$m_1$and $m_2$are averages for $z_n\in$ class 1 and z_n class2 respectively

$s_1$and $s_2$are variances for zn∈ class 1 and $z_n\in$class2 respectively

The variables are so defined as :

$$(m_1-m_2)^2 = (w^T\mu_1 - w^T\mu_2)(w^T\mu_1 - w^T\mu_2)^T \quad (21)$$

$$(s_1+s_2) = w^T\Sigma_1 w + w^T\Sigma_2 w \quad (22)$$

Where,

μ_1 and μ_2 are averages for $x_n\in$class1 and $x_n\in$class 2 respectively

Σ_1 and Σ_2 are variances for $x_n\in$class1 and $x_n\in$class2 respectively.

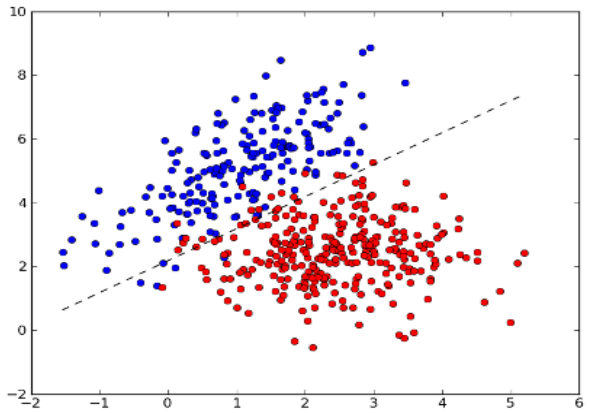

Figure. 4 Binary Classification using LDA

An example of classification shown below

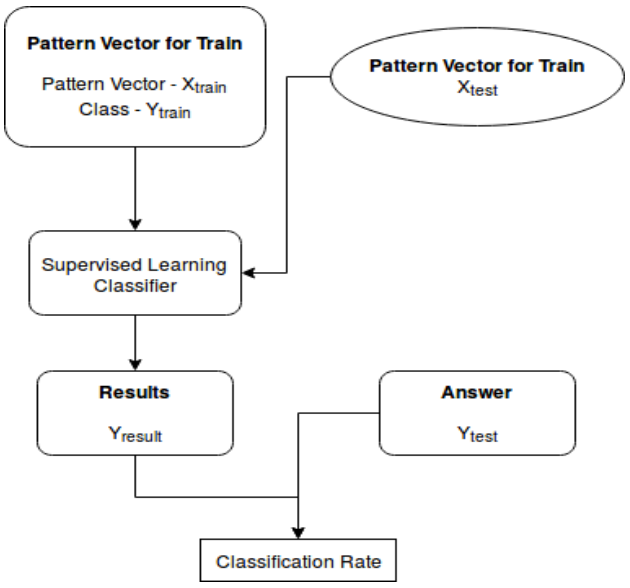

Figure .5: Workflow of EGG Classification

3. Hardware Interface

For demonstration of computational capability of BCI in real time, it integrated with a fixed wing UAV (2-command Control) and to multi rotor (4- Command Control).

3.1. Delta Wing

The testing was done on a model first, before conveying it in genuine flight. The yield from the expectation structure (LDA based 2 class classification) is sent to a microcontroller unit. An Arduino (ATmega328P) board is utilized to control a model elevon of a delta configuration made of chloroplast. The model is pre-customized to complete a specific activity with the assistance of servo engines relying on the sort of input directions got. The fig underneath (Fig. 6) demonstrates the working model.

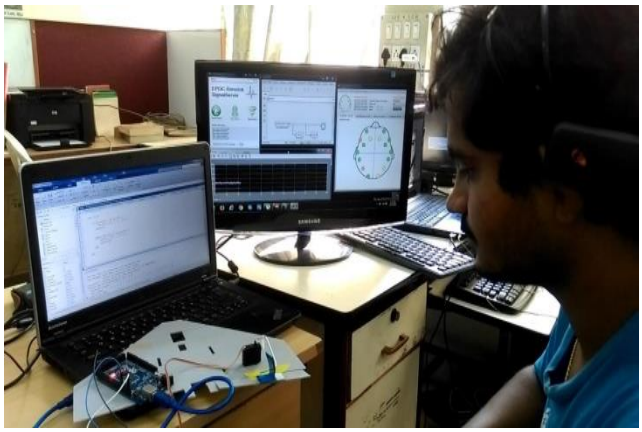

Figure .6: Prototype Demonstration

3.2. Multi Rotor

With the end goal to set up a proof of idea, an off-the-rack quadrotor UAV stage (Fig. 7) perfect with the Python programming dialect was utilized.

Figure .7: Parrot AR used for testing

The calculation, likewise composed in Python, is facilitated on a ground station that is in steady duplex correspondence with the UAV by means of WiFi. The UAV have a variety of flight instruments, for example:

- front camera
- bottom camera (low field-of-view)
- 3-axis accelerometer
- 3-axis digital compass
- a magnetometer
- barometer
- ultrasonic sensor
- motherboard

The internal control circle program is inserted onto the mother board while the external route circle is directed by an open-source Python library called python-ardrone which is facilitated on the ground station. Sensor information combination is accomplished by utilizing Broadened Kalman Sifting (EKF) technique widely. The executed calculation sends just high-level directions (NLSVM based 4-class classification) to the UAV stage (Fig. 8) with the goal that the intrinsic dependability isn't bargained.

Figure .8: Real time testing

4. Results

The interface works truly well progressively [18], at a rate of 90 Hz. Singular consequences of each subject have been arranged beneath:

TABLE I: Performance Evaluation

Subject	A_{LDA}	A_{NLSVM}	T_{focus}	T_{max}
1	81%	79%	150 s	287 s
2	83%	83%	143 s	295 s
3	82%	79%	156 s	304 s
4	89%	83%	151 s	309 s
5	85%	80%	144 s	322 s
6	77%	78%	139 s	254 s
7	82%	81%	149 s	322 s
8	79%	77%	155 s	330 s
9	87%	82%	129 s	310 s
10	98%	96%	133 s	505 s
11	91%	88%	143 s	303 s
12	92%	90%	166 s	367 s
13	90%	85%	162 s	332 s

where, A_{LDA} speaks to the testing precision for LDA (2class),A speaks to the testing precision for Non-Linear SVM (4-class) classifier, T_{NLSVM} speaks to the normal time

taken to center around a specific engine symbolism assignment T_{max} and T_{focus} is the most extreme center time. *The expanded execution if there should be an occurrence of subject 10 could be credited to the way that the subject had been doing Yoga for a few years. Yoga has been known to improve mental what's more, physical execution as far as memory, center length (Akhtar et al. [16]) and physical stability (Omkar et al. [17]).

5. Conclusion

A system was developed which takes EEG (electroencephalography) signals as input, modifies the signal for feature extraction and interfaced with elevon for controlling it wireless connection. The raw EEG data was extracted from the brain of the subject using the EMOTIV EPOC+ headset.

The raw EEG data is a result of only intuitive thinking without any actual physical movements. The data was then transformed in a suitable data form to be processed. Further removal of artefacts, unwanted frequencies and irregular data was done. The processed data was then used for preparing the model for machine learning using LDA analysis method.

Suitable markers to mark the Event Related Potential (ERP) to train the machine for evaluate were added. A twin dataset is applied to the created model, to calculate the misclassification and the error percentage in the same dataset and the twin dataset respectively. The error percentage is 11%.

An offline analysis was done by encoding the signals into commands for the fixed wing Elevon. The final interfacing was done with the Elevon and the repeated creation, testing, evaluation, and deployment of the models were done to reach this accuracy. The BCI is also tested on an off-the-shelf multi-rotor, with classification accuracy as high as 90%, for 4-class based control. This work can further be extended to control other kinds of UAV and the complexity can be increased and customized based on the requirement. The modularity, remote access and control of interfaced Elev on based on pure brain signals in a BCI system demonstrated.

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