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Brain-Computer Interface using Electroencephalogram signatures of Eye Blinks

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Abstract

The objective of this work is to develop a personalized eye blink based communicator device. The eye blink is detected using a single channel Electroencephalogram (EEG) system with a Bluetooth interface. Eye blinks have predominant signatures in EEG. Different patterns based on these signatures are used to map alphanumeric characters on a virtual keyboard and words are generated. Voice module is incorporated into the app on the android device for better accessibility of the device by including Text To Speech synthesizer (TTS) at the back-end to produce speech output.

Index Terms: Brain-Computer Interface, EEG, Text To Speech synthesis, eye blink prediction, Android app

1. Introduction

People with speech disability as a result of conditions like paralysis/cerebral palsy require personal assistants that interpret their motor-disabled gestures to communicate with the outside world. With eye blinks as gestures, our objective is to develop a Brain-Computer Interface (BCI) with a single channel EEG device. Eye blinks can be prominently identified in the EEG signal and can be easily predicted using time series analysis. In [1], a complex probabilistic neural network is used as a binary classifier for eye blink detection. Using three channels EEG, a simple threshold-based eye blink detection system is proposed in [2]. Our proposed model uses threshold based eye blink detection system with a single channel EEG.

By using an eye blink detector as an input device, a person may be able to communicate with smartphone apps to get simple chores done. In particular, mapping EEG eye blinks signal patterns to keyboard actions can be used to form words and sentences. In [3], a BCI using eye blinks in a multiple channels EEG device, obtained a throughput of one character per minute. In the proposed work, we use word completion models to reduce the number of eyeblinks. The system interacts with a text to speech synthesis system and outputs the speech corresponding to the word the user intended to speak.

The rest of the paper is organized in the following manner. Section 2 focuses on the hardware and software tools used to build BCI. Section 3 concentrates on the methodology to detect eye blinks and interface on T9 and ABC keyboard. Section 4 discusses the conclusions and future expansions.

2. Tools

This section explains the hardware and software tools used to build BCI.

2.1. Mindwave device

A Mindwave mobile+ [4] device with Bluetooth connection is used for EEG data acquisition at a sampling rate of 512 Hz. Mindwave headset transmits timestamp, raw signal, signal level, attention, meditation, and strength of frequency bands. The raw signal is quantized potential difference measured between frontal and earlobe.

2.2. Android Studio and Java Complier

This project is developed on Ubuntu 16.04 LTS powered by Andriod Studio 3.0.1 and Gradle 4.1. The project is compiled using Java 1.8 and Android SDK API 26. Minimum SDK requirement is SDK API 14.

2.3. Android Mobiles

The project is tested and evaluated on Oppo A37F with Android Version 5.1.1 and API 22, Micromax Q427 with Android Version 6.0 and API 23, and LG Q6 with Android Version 7.1.1 and API 25.

3. Approach

This section explains the methodology to detect eye blinks and interface on T9 and ABC keyboard.

3.1. Preprocessing the signal

Since the raw signal is acquired using Bluetooth communication, noise may be present in the signal. To remove noise, moving average ($\mathcal{M}_n$) is used to smoothen the signal, as shown in Figure 1.

$$\mathcal{M}_n = \frac{\Sigma_{i=n-m}^{n} t_i}{m}$$

where, t_i is the quantized EEG signal at the time instant i, n is the current time instant and m is the number of samples used for moving average. Empirically we found that $m = 50$ works best.

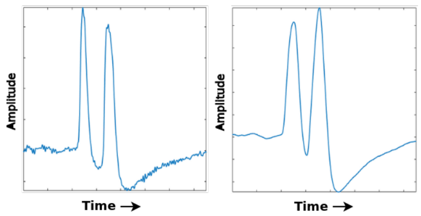

Figure 1: *Raw EEG signal and corresponding moving average*

3.2. Personalized threshold

A slight misplacement of the EEG electrode may influence the strength of the signal to a large extent. Initial twenty seconds are used to calibrate the personalized threshold for each individual.

$$\text{Personalized Threshold} = \mu_{\mathcal{M}} + (2 \times \sigma_{\mathcal{M}})$$

where $\mu_{\mathcal{M}}$ and $\sigma_{\mathcal{M}}$ are the mean and standard deviation of moving average $\mathcal{M}$ respectively. It is observed that two standard deviation from the mean is effective in predicting the eye blinks.

3.3. Eye blinks prediction

Numerous samples were collected from various subjects with voluntary eye blinks. Empirical analysis of these samples shows that a human eye blink lasts for 500 ms and the time gap between the two voluntary eye blinks is less than 1000 ms. The moving average ($\mathcal{M}$) of the eye blinks monitored using a timer with a waiting period of 1000 ms. Once it crosses the threshold, a timer thread is initiated with a waiting period of 1000 ms. Every time $\mathcal{M}$ crosses the threshold, blink count is incremented, and the timer is reset to 1000 ms. Once the timer is elapsed, count of eye blinks is returned to the interface.

3.4. Virtual T9 Prediction Keyboard

T9 stands for Text on Nine keys, uses nine keys to represent all English alphabets as in Figure 2. It does not require multi-tap approach used in traditional mobile phone keyboard. The virtual T9 keyboard is partitioned into four regions, namely keypad region, current word region, suggestion region, and phrase region. Key navigation is facilitated by highlighting each key in a cyclic way using a three seconds timer. The highlighting process begins from the keypad region and navigates to other regions based on the user input. In the keypad region, the user can choose the highlighted key by responding with two eye blinks. Once a character is chosen, the character is appended to current word region, and five suggestion words[1] are displayed in the suggestion region. The words in the suggestion list will also be highlighted one after the other with a three seconds timer. Again the user can select any one of the highlighted words from the suggestion list with two eye blinks. The chosen words will be accumulated in the phrase region. Backspace button will be highlighted for three seconds. Blinking twice in that span of time will remove the last character in current word region. Then phrase region will be highlighted for three seconds. If the user blinks twice in this three seconds span, the words in the phrase region are sent to TTS, and the synthesized speech is played. This process repeats infinitely until the application exit[2].

3.5. Virtual ABC Prediction Keyboard

The design of virtual ABC keyboard, shown in the Figure 3 is similar to the design of the virtual T9 keyboard. Virtual ABC keyboard comprises of all the features as in the virtual T9 keyboard, along with the accessibility to speak nondictionary words, say names. Incorporation of processes of highlighting, typing, partial word completion model, navigating through suggestions, choosing a suggested word, appending words to the phrase region and playing the synthesized speech from the phrase region through eye blinks are same as mentioned in section 3.4.

[1]These top five words are predicted using Google web trillion-word corpus [5].

[2]A demo video is available in https://www.iitm.ac.in/donlab/IS/DemoBCIusingEEGofEyeBlinks.mp4.

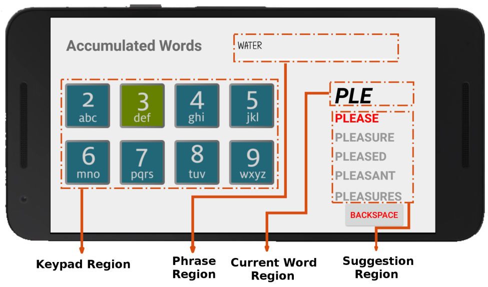

Figure 2: *Screenshot of Virtual T9 Prediction Keyboard*

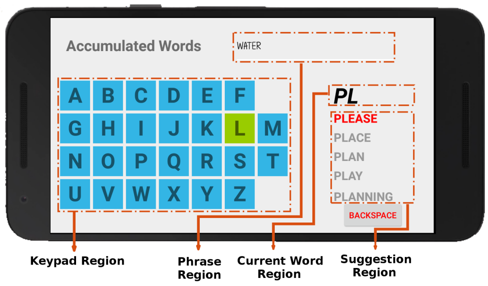

Figure 3: *Screenshot of Virtual ABC Prediction Keyboard*

3.6. Speech synthesis

The accumulated words from the phrase region interact with Android Text To Speech (TTS) synthesizer API 4 [6] for speech delivery.

4. Conclusions and future work

In the proposed work, a BCI is developed for persons with speech disability where EEG based eyeblinks are detected to produce a sequence of English words that are finally synthesized to produce speech output. The next challenge is to design similar keyboard and speech output interfaces for Indian languages.

5. References

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