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Emotiv EPOC Bengali brain computer interface controlled by single emokey

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Abstract*:*

Brain-computer interfaces (BCI) need both hardware and software supports which are generally expensive and one of the main reasons behind they are not affordable for many people around the world. Emotiv EPOC is one of those devices in the present market which can provide electroencephalograph (EEG) signals and explain the brain activities. Before P300 based BCI was well known to the researchers for clinical uses and BCI applications. But in this paper it is reported that, the main challenge for designing a larger matrix based BCI speller can be solved in a different way. Proposed novel matrix algorithm and emokey feature can help to build large matrix. Here for the current study, the matrix size was 7x19 (RC) and 133 symbols were mapped. Generally it is harder to classify the symbols with fixed frequency in a larger matrix cells and the method was followed by many BCI researchers. BCI virtual speller was one of the important applications for the severely disable people. In this paper, Bengali BCI matrix speller is designed for the first time for Bengali speaking people around the world. This speller is also useable for the social networks, writing simple documents and daily life communications over internet. For this virtual keyboard novel matrix algorithm is applied and controlled by eye blinking single emokey. Emokey has a great feature which translates emotional states. It helps to provide a simple input or send specific keystrokes for the application. In this paper, it is presented that the ITR (Information Transfer Rate) is 29.4 bits/min and typing speed was average 7.43 symbol per minute (SPM) and had an accuracy average 94.12% in the experiment.

Keywords-Component: *Brain Computer Interface, Emotiv EPOC, EEG, Virtual Keyboard, Matrix speller*

I. INTRODUCTION

Brain-Computer Interface (BCI) is one of the important research fields due to its necessity and technological advancement. The target users of BCI are usually patients from severe motor disabilities like progressive muscular dystrophy, cerebral palsy (CP) and spinal cord injuries (SCI) [22]. Non-invasive interface based on EEG has already been used successfully by the group of people whose motor performances are also damaged in certain injuries. It has been observed by Guger et al. that more than 80% healthy people can use such a BCI [4]. Application areas have been extending in web browser navigation [11], wheel chair navigation [3] and time aligned information provided by BCI such as user emotions or cognitive load for different purposes [5], [10]. For assisting disable people in communication and rehabilitation, P300 based speller has been studied by the researchers largely. A typical ERP (Event Related Potential) based P300 row/column paradigm (RCP) speller was first introduced by Farwell and Donchin in 1988 [24]. After that different matrix speller was proposed like checker board paradigm (CBP), lateral single character (LSC), auditory ERP speller, region based paradigm (RBP) and single display paradigm (SD) etc. There are also steady state visual evoked potential (SSVEP) based

speller such as Breman-BCI, intendiX, AIRlab-BCI and hex-o-spell etc. Although, P300 speller was initially designed to spell Latin characters later Chinese character was proposed in 2010 [20].

Nowadays, besides P300 there are few devices like in the market which can provide such a quality service to the BCI researchers and other users. Low cost, wireless and lightweight device like Emotiv can change the present number of BCI application users. Mostly the country like Bangladesh, India, Pakistan or other with huge population and same economical conditions could get a good support from this low cost BCI hardware system. Actually, Emotiv was aimed at the game market and is not classified as medical device. Duvinage et al. compared with a medical device and showed that it records real EEG data [27]. Their study shows that, performance is not better than a medical device but it is not recording only muscular or ocular data criticized by some BCI researchers. Emotive EPOC is getting popular day by day. It has given a huge opportunity by providing a feature Emokey with the main control panel. Emokey can identify user's emotional activities and facial expressions. It can be used for future works. Speller was also developed for Emotiv users and even tested for P300 based applications [15]. Emotive app store is also providing Emokey based keyboard for the Emotiv users [28]. Among them, user can choose cognitive or facial actions to control the keyboard. In this study, enhancement of matrix based Bengali virtual keyboard was focused.

II. PROPOSED MATRIX SPELLER

In this study for designing a Bengali speller was a challenge indeed. Bengali language has vowels, consonants, miscellaneous and numbers in total which make a huge figure around 90. To make a full typing keyboard, the most necessary punctuations are added in the keyboard layout. Backspace, enter button, space and necessary symbols are also used in this interface. Moreover, symbol of "›" will give an extra advantage to return from the error selected column.

For this current study, the matrix size was 7x19 (RC) and all the necessary alphabets and punctuations nicely placed there. The algorithm works in order to highlight only the column by vertical flashing from left to right side for selecting necessary character. Then it starts to flash again from up to bottom and letter by letter for selecting the user's desired character in the specific column selected before. The Keyboard repeats these two steps again to write another character. If any user wishes to get out of the wrong selected column, there is "›" symbol in each column to start from the beginning. A trick can also be applied if any user miss the expected column then again the keyboard will pass through all other non target columns. So, to skip this or not to pass through all non target columns in the right side, any random column can be selected and then restart symbol will start flashing from the very first column.

User will be used to familiar with the keyboard map day by day and whole process will be easier and faster then. Normally there is backspace to correct the spelling also. It is possible to write more character in a minute, if the user doesn't select any character from last columns. 400 ms was the optimum time interval for this application. It is fixed for selecting a whole column and then a character from it. During test session it was observed carefully that the time delay between user's eye blinking and response from Bengali emo keyboard

were slightly different. So, it was fixed by testing several times and 400ms were average time delay to synchronize well.

When the device is connected wirelessly, the control panel can create different user profile and save their emotional states like blinking, smiling and other few actions. It shows that the EEG signals were classified by the built in classifier. Emokey sends the necessary key like 1 was set for Bengali keyboard, which helps user to choose the full column and then the letter from the selected column. It works like a switch where the user only decides when they need to be on or off. So, it can select a character in two steps only which is also a positive advancement for BCI spellers. It will help the user to interact with it very easily in two steps.

III. INTERFACE DESIGN

Bengali Emo keyboard was mapped for the first time and there were a lot of things to be pointed out. The proposed matrix speller with only vertical or column flashing helps to select a character. For Bengali keyboard it was needed to place the most necessary vowels and consonants in near matrix cells. As the matrix flashing starts from the left each time and then follow the series. It takes slight extra time to select the last letter placed in the 19th column. It was examined during interface design and to apply the proposed algorithm less useable consonants, numbers and punctuations placed in the matrix after 10th column. The advantages of the interface were like it can be useable with any web browser, windows default text, notepad and MS power point to write. The Fig. 1 shows that how a subject can write in normal windows text. As the alphabets were mapped with Unicode characters, so the file should be saved in Unicode format.

Figure 1: Writing with Bengali matrix speller on normal text document

Like all other BCI applications, the performance will be much better with training and leaning by keyboard layout. The color of the user interface was comfortable to concentrate. The ISI (Inter Stimulus Interval) is 400ms. But there is no different frequency for the characters like standard matrix speller were proposed by Farwell and

Donchin. The proposed Bengali matrix speller also can communicate with social sites. Fig. 2 shows that how can a subject share status in social sites like Facebook. Mostly used punctuations will give a support to write any kind of documents with the help of Bengali Emo-keyboard. The width and height of the keyboard interface is 800 x330px. It can be a sample for different languages to make their own BCI spellers. It has the opportunity to map different Unicode characters. It means that it is possible to write almost all language supported by the Unicode map. The keyboard option was hooked in the code of the application. It will mostly look like ordinary virtual keyboard and which is another different approach from previous BCI spellers.

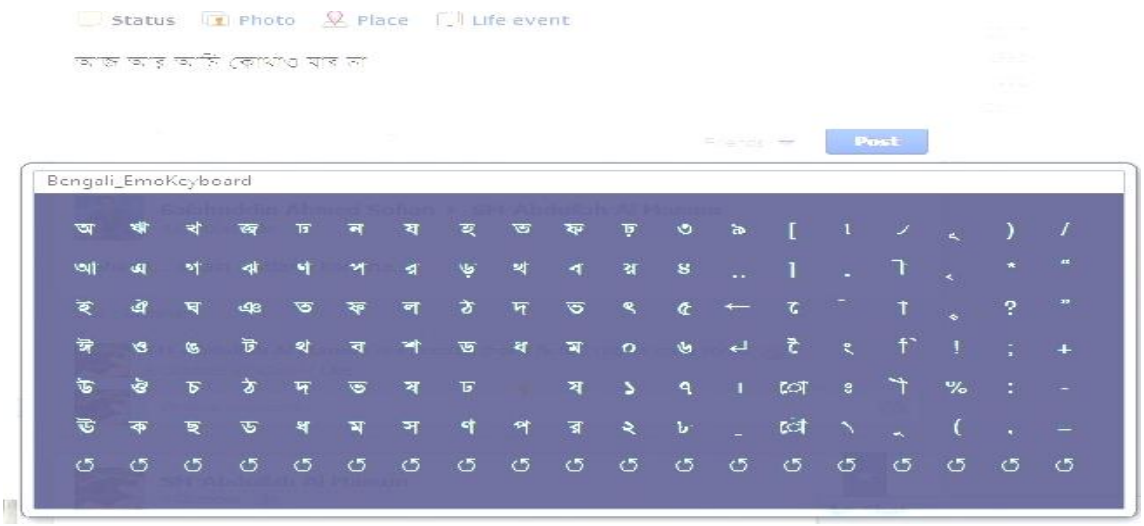

Figure 2: Bengali matrix speller can connect disable people with social site like Facebook

Search engine like Google can search necessary document which is titled in Bengali language. So, Bengali BCI matrix speller can help the user to write in Google search engine for a Bengali document. Fig. 3 shows that how to search in Bengali language.

Figure 3: A view of using Google search engine for Bengali document with Bengali matrix speller

For this keyboard Bengali writing font Solaimanlipi is used. Font size is 14 for the keyboard layout itself and writing font size is 12. Emotiv EPOC which is wireless and non invasive can be useable for a few hours without any problem. It is easy wearable and maintainable also. Emokey is available in research version of its own SDK.

This is main feature that has been applied in this study and because of its different options user can select comfortable emotional state to choose the key for this keyboard application. Single emokey will give an extra support for any disable person to remember and repeat it easily. In this design, user advantage was given much priority. The application is designed in Microsoft Visual Studio 2010 with Visual C++ for windows OS.

IV. EXPRESSIVE SUITE AND ACCURACY OF THE EMOTIV SYSTEM

Emotiv's control panel provides different tools which can detect facial expressions, emotional states and imagery motor movement. It sends data to the computer at the rate of 128Hz. The expressive suite provides detection of a range of facial movements. Expressive suite actually concerned with electromyography (EMG) presents among the EEG. Emotiv systems itself classify the detected EMG movement into facial expression group and allow the fixed key value to be another form of input electrooculography (EOG) is also present that similarity and classified for looking left or right from the EEG signals [25].

The initial set of facial expressions are: eye blinks, winks, smile, clenching of teeth, movement of eyebrows, left smirk, right smirk, left spin and right spin. Most of the people have quite similar facial muscle and that is the reason the expressive suite doesn't need to be trained by every individual repeatedly [25]. However, the Emotiv software is still in a black-box as there is no published information about performance of the algorithms. Cernea et al. examined the given classification accuracy by Emotiv for detecting different facial expressions [7]. The result was remarkable and impressive. The results were varying 70%-100% correct depending on specific facial movements.

Another study had taken place to explain the accuracy of the expressive suite by adding classes. Herger et al. achieved accuracy about 81.8%, which is also note able for future works [4]. For the current study, mostly eye blink was given much attention and the result published by Herger et al. matched closely [9]. From their results for smile the accuracy was about 89% and blink was 98% [9]. It was also focused for current study to get a much better performance. Comparing to facial expressions, cognitive actions were not successful as the rate was found 46.83% with the built in classifier [25]. But in other research with different classifiers, German autonomous car and a tractor were successfully controlled by the cognitive actions [8], [17]. Finally, an experiment was set up in embedded systems design lab at Istanbul Technical University (ITU) to check the performance of the speller and classification accuracy of emokey as input.

V. EXPRIMENT SESSION

The experiment was necessary to understand the ITR (Information Transfer Rate) and performance of the speller. There was no source of information provided publicly about the classifier used by Emotiv. So experimental results published by different researchers were used as standard for this current study. To understand the approximate performance of the first Bengali emokey supported Keyboard, 3 different subjects attended in the experiment arranged by embedded systems design lab. All the subjects have age limit was from 22-25 and their native language is Bengali.

A. Experiment setup:

- BCI system is always new to most of the subjects. They don't have any detail information about using or related functions. For this experiment with healthy and normal three male subjects were selected and they were given some preliminary concept about how the whole system works. So, it was a very new experience for all of them. For the current experiment eye blinking was comfortable and preferable for all. In total three different training sessions and one final session were prepared for them to perform well.
- They were given the layout of keyboard right before the experiment. Bengali keyboard interface was differently mapped for the used matrix algorithm. Actually there was a matter of synchronization of user intended command and application's response. In other studies like Brain driver, a slight delay was found for the application when the experiment had taken place [2].

B. Result of the experiment :

Experiment in the lab environment was quite and the subjects were given task after three training sessions. Herger et al. used linear support vector machine (SVM) as a classifier and the classes for eye activities were blink, left and right. The accuracy grained in the classification was 98% for blink [9]. To check the approximate ITR (Information Transfer Rate) the following formula is used (1).

$$\mathrm{ITR} = \frac{N_c}{T} \log_2 |\mathcal{A}| \qquad (1)$$

Here, Nc represents correctly typed characters and $|\mathcal{A}|$ is the size of the alphabet. Wang et al. described the formula in their recent study and explained why it is preferable than mostly used ITR formula [26]. T is the total time of selecting characters. Three different experimental sessions were also designed for a subject to observe the progress. If the subject has no idea about BCI, then after certain time performance will be better and a similar graph has shown here in Fig. 4. The subject has given a task to write 15 characters where space was included in the character counting. "তুমি কেমন আছো ? / How are you?" is the sentence selected for the subject to write.

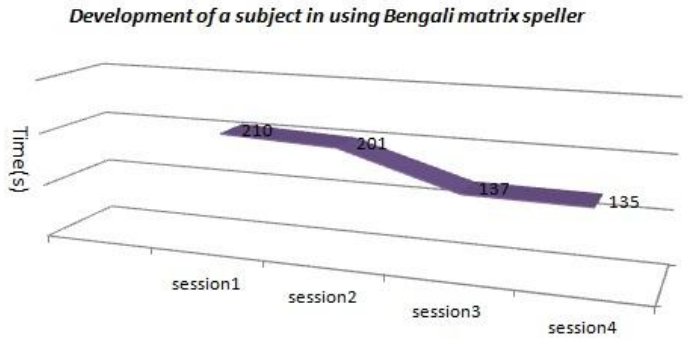

Figure 4: Development graph of a subject in using Bengali matrix speller

Herger et al. published 98% accuracy, which was classified by using linear support vector machine (SVM) [9]. For the final given task and ITR calculation, 17 characters were expected to write correctly, backspaces were not counted as correct characters as explained by Wang et al. in their study [26]. Results in the table shows that the accuracy average was 94.12% for the subjects. It can be expected that daily use can improve the percentage to the higher level. Error calculation was done by the wrong selecting characters and number of characters need to be written in the task. Mostly in the training sessions error is common and accuracy level is lower. But it improves with the time and it is shown in the figure 4. The graph with time was taken by the subject in different sessions for the same task. It is clearly improving in session 4.

Experiment session:

Participant	Given task of 17 Characters & a full sentence : আমার সোনার বাংলা। [My golden Bangla]			
	Durations(sec)	*Age*	*Mistakes by the subjects*	*ITR(bits/sec)*
S1 (M)	130.2	22	2 (11.76%)	0.51
S2 (M)	144	23	0 (0.0%)	0.48
S3 (M)	137.4	25	1 (5.88%)	0.49
Average	137.2	Accuracy	94.12%	0.49

Table 1: Experiment results and ITR (Information Transfer Rate) calculation

Here from the table 1, the average time for writing 17 character were 137.2 sec. The ITR average for all 3 subjects was 0.49 bits/sec or 29.4 bits/min. So, as a BCI speller it was successful to write at a rate of 7.43 char/min. Higher performance can be found in case of different words writing [13]. The matrix of 19 columns long takes a bit extra time if desired character placed at the last columns. Moreover, it was reported by Davide

that writing speed were 6-8 char per minute for the Emotiv's Minkeyboard application [6]. It was approximately similar to the result found in the experiment for current study.

The performance can be lower for disable people but it can improved by using in a regular basis. Test sessions were recorded at university lab. Mostly it was quiet and better than noisy area or house near a road side. According to Ortner et al. BCI P300 speller got more successful results from healthy subjects at lab environment [29]. They also explained about the results of nosiy environment and lastly people with motor impairments. Where healthy people in a lab environment reached at average 91% accuracy, in the other experiment the target people group with motor disabilities reached about 62%. So, recored results for the current study can be found lower in different environmets and for motor disable people. The experiment results for Bengali matrix speller has showed a writing speed near to Berlin-BCI and there result was 7.6 char/min [1]. It was demonstrated in world's largest IT fair CeBIT. So, it can be hoped that expected result can be found by the patients for Bengali matrix speller in a public session.

VI. CONCLUSIONS

Emotiv EPOC device can expand the number of present BCI system users and healthy people. Nowadys many people are also interested in using this new technology for different purposes. Mostly, BCI research has been driving for performance improvement in English spellers. There are many research sources for BCI interface designing, ITR (Information Transfer Rate) calculation [19] and Classifier accuracy for English spellers. There is also research in different language spellers but very few in number [18], [20], [23]. So, still many disable people can not express their emotions in their mother language. This study was a part of the progress. This keyboard map and method can be used for those langauges which consists of minimum 80-130 necessary alphabets or puncuations. It is still a problem to make a faster and easier speller for disable persons which languages are consits of higher number of characters.

In this paper a major problem was solved. In P300 based BCI spellers or steady-state visual evoked potential (SSVEP) based spellers designed mostly by fixing different frequencies. It is hard to classify them and the probability of selecting a wrong symbol is higher. But in the proposed matrix speller only the classification of eye blinking is enough to get a result. It shows higher accuracy is possible to select a symbol from a large size matrix with the proposed algorithm. In this current study a matrix based Bengali speller was designed and examined. But there are also challenges for this interface. Firstly, it seems slower because the user must wait for highlighting the correct symbol to select. But the general speed was 7.43 characters per minute which is hopeful.

The designed Bengali matrix speller can open a new way to write Hindi, Tamil, Telegu, Urdu or similar number of characters. Especially South Asian languages. This BCI speller will support many disable people to express their words. Social networks like Facebook, Myspace and Twitter can be connected to express their desire. Present P300 spellers are far from daily use in clincal or commercial uses. To leave the BCIs from laboratories extra effort will be needed [16]. But there are some exceptions, like intendiX has been proposed in 2009 [23]. Bengali Emokeyboard speller works mostly like a normal virtual keyboards. So, this new interface can

give a support and different experience to other users. They can use with windows system and it doesn't require any mathlab or any extra software support except Emotiv EPOC control panel provided with the package.

ACKNOWLEDGMENT

Author would like to thank Dr. Zafer Işcan, now working as a Postdoctoral Research Associate at Stony Brook University of New York. Thanks to embedded systems design lab of Istanbul Technical University for conducting the experiment sessions and the Emotiv EPOC device they have provided.

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