УДК 57.087.1

A STEP TOWARDS THE SOLUTION OF THE ILLITERACY PHENOMENA IN SSVEP-BASED BCIS

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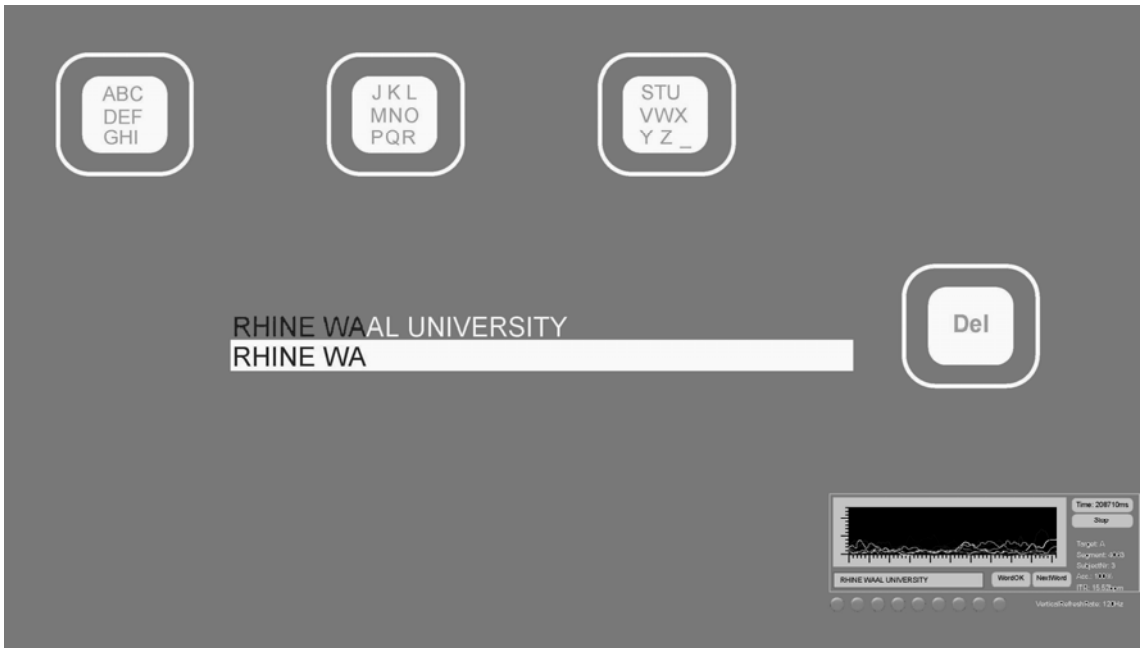
In this paper, we present an adaptive approach for classification of SSVEP-based BCI signals. In a series of studies, we have shown that this method has the potential to solve the problem of so-called BCI illiteracy, when users are not able to successfully operate the system. The maximum duration of a single classification can be up to 16 seconds, but absolutely all of the subjects were able to successfully manage this interface.

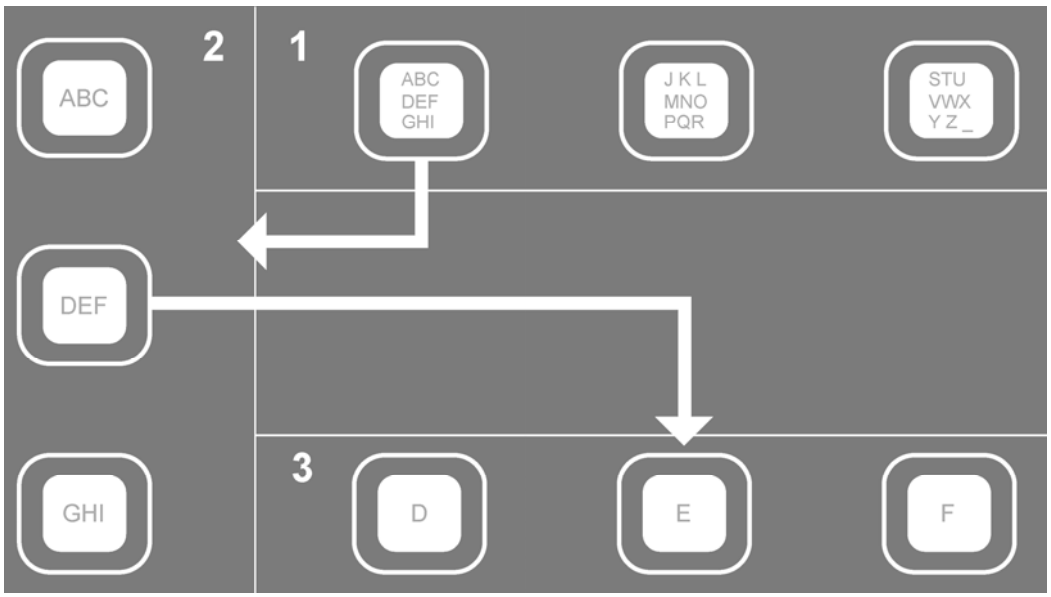
Maximizing accuracy while maintaining adequate speed is a major challenge in the development of brain-computer interfaces (BCIs). Steady-state visual evoked potentials (SSVEPs) are the continuous brain responses elicited at the occipital and parietal cortical areas under visual stimulation with specific constant frequencies; they can be used as an input for reliable non-invasive BCIs which translate normal brain activities into commands for communication and control [1]. A major problem regarding BCI performance is so called BCI-illiteracy (also called BCI-deficiency). Many articles reported subjects that were not able to gain control over the BCI systems (the command accuracy was not above chance level) [2].

There is a strong correlation between BCI-accuracy and the length of the time window dedicated to the SSVEP classification during EEG analysis. The relevance of the choice of appropriate time segment length tailored in relation to the user and the desired accuracy has been intensively discussed already in 2010 [3]. In a performance comparison on 8 different time segment lengths over 10 subjects the authors analyzed the distribution of the time segment length for all correct classifications. The average time segment length for obtaining a SSVEP response recognition of 95% was 2.8 s. It was also mentioned, that reliable SSVEP response detection cannot be achieved under 0.75 s with the used classification method. In general a short time window results in classification errors, and a long time window slows down the BCI performance. In many practical experiments with subjects we found out that some users need to gaze at the stimulation target for a relatively long period of time, hence a long time window seems to be necessary to achieve control of the BCI system.

An adaptive mechanism of time segment length adaption for SSVEP command classification has been introduced in [4]: All classifications were performed on the basis of the hardware synchronization of the used EEG amplifie (g.USBamp); the new EEG data were transferred to the PC in blocks of 13 samples (101.5625 ms with the sampling rate of 128 Hz used). In this study, three time segment lengths were chosen as 812.5 ms (8 x 13 samples, or 8 blocks of EEG data), 2031.25 ms (20 blocks) and 4062.5 ms (40 blocks). Every BCI command classification was performed with the sliding window T_s after the evaluation of the new EEG data block. In the case where no classification can be made and the actual time *t* allowed the extension of the T_s to the next predefined value, this new value was used instead. An application of this method facilitated a huge boost in the BCI accuracy.



a



b

Figure 1 – GUI of the Three-step spelling application. Initial screen containing the alphabet in three flickering boxes (a). An overview of the three steps necessary to choose a single letter (b)

The Three-step spelling application [5] resembles an earlier developed graphical user interface (GUI) layout [6,7]. The initial screen is displayed in Figure 1a**.** Four commands were represented on the computer screen by flickering boxes of default sizes (125 x 125 pixels). The size of the boxes varied during the experiment as described by [4]. After selecting a desired box, the position of the three boxes containing the alphabet changed from upper horizontal to left-hand vertical according to the first selection made [5]. After the second selection the positions changed once more from left vertical to horizontal bottom position. Also, each box now contained a single letter. In the second and the third step, the far right box ("Del" in the first step) would contain the command "back", giving the user the option to switch to the previous view. An overview of the three steps necessary to choose a single letter is shown in Figure 1b.

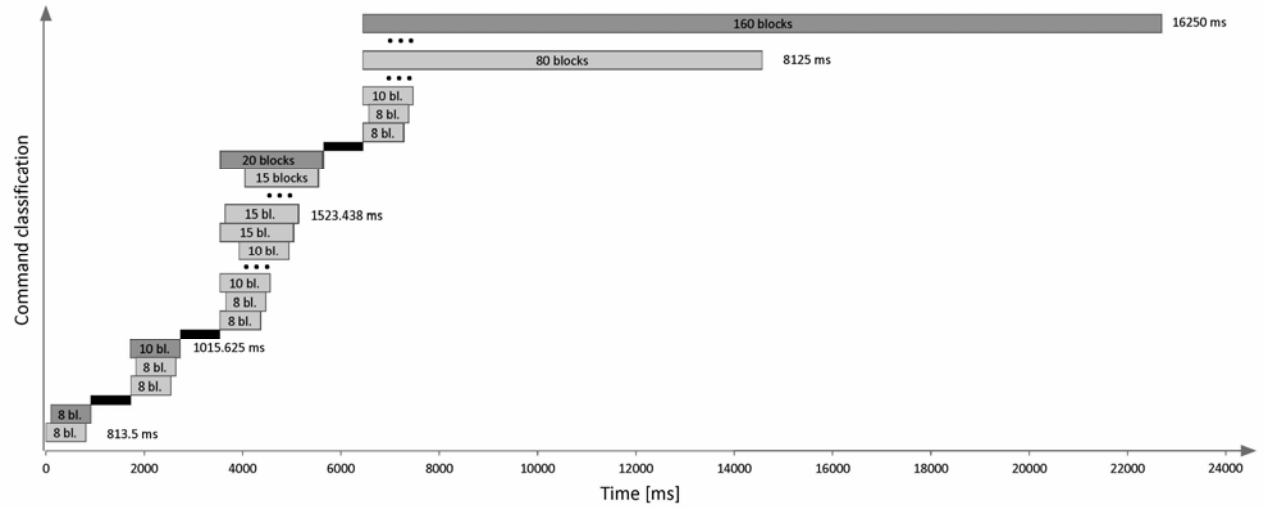


Figure 2 – Changes in the time segment length after a performed classification in case no distinct classification can be made and the actual time t allows the extension to the next pre-defined value. After each classification (dark grey), additional time for gaze shifting was included (black) and the classifier output was rejected for 9 blocks

Every command classification was followed by an audio feedback in order to reduce the information load on the visual channel.The SSVEP classification was performed on the basis of the adaptive time segment length of the acquired EEG data [4]. If no classification could be made and the actual time t allowed the extension of T_s to the next predefined value, this new value was used instead (see Figure 2**)**. The fixed starting segment length was determined by the wizard software. We further included a segment length of 160 blocks [8]. Recently we modified this adaptive method further. As computers are getting faster and more powerful, there is no need in limiting the number of fixed time segment lengths to only three. In order to make the system more robust we limited

the number of simultaneously presented stimuli to four, we extended the time windows to 8 and 16 seconds length and increased the number of time segment lengths (shown in Table 1 and Figure 2**)**. In a recent study [8] we tested the modified system. We compared the performance of a SSVEP-based BCI spelling application of two different equally sized age groups (five subjects each, ranging from 19 to 27 years and 66 to 70 years). Results showed that elderly people may have a slightly lower information transfer rate (ITR) and that their classification time window was usually larger. Some of those elderly subjects might have fallen in the illiterate-category if fixed segment lengths as with the previous software version would have been used. In another research study those classification time windows were used for a BCI spelling performance analysis with 61 subjects (mean age 22.8 years). All subjects were able to control the system (mean accuracy 97%).

This proofs that the introduced modifications are an essential step towards full BCI literacy. We are currently developing a system that implements even more fixed time segment lengths and on an automated calibration process that determines the optimal variation of individual time segment lengths, as e.g. between 4 and 16 s (next to other BCI key-parameters) for each user individually. We believe that the BCI-illiteracy problem for the SSVEP-based BCIs is solved now, as a sufficient extension of the time window seems to enable poor performers as well as previous BCI-illiterates to gain accuracy and control over BCI systems.

Table 1 - Overview of the used time segment lengths. Eleven segment lengths between 812.5 ms (8 x 13 samples, or 8 blocks of EEG data) and 16250 ms were used

Time [ms]	813	1016	1523	2031	3047	4063	5078	6094	7109	8125	16250
EEG data blocks	8	10	15	20	30	40	50	60	70	80	160

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Анотація

КРОК НА ШЛЯХУ ВИРІШЕННЯ ПРОБЛЕМИ SSVEP НЕОСВІДЧЕНОСТІ НА ОСНОВІ BCI

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В даній статті ми представляємо адаптивний підхід для класифікації SSVEP сигналів так званого брейн-комп'тер інтерфейсу. В ході серії досліджень ми продемонстрували, що цей метод має потенціал для вирішення проблеми так званої BCI неосвідченості, коли користувачі не в змозі успішно керувати системою. Максимальна тривалість однієї класифікації може доходити до 16 секунд, проте абсолютно всі досліджуємі були в змозі успішно керувати цим інтерфейсом.

Аннотация

ШАГ НА ПУТИ РЕШЕНИЯ ПРОБЛЕМЫ SSVEP НЕГРАМОТНОСТИ НА ОСНОВЕ BCI

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В этой статье мы представляем адаптивный подход для классификации SSVEP сигналов так называемого брейн-компьтер интерфейса. В ходе серии исследований мы продемонстрировали, что этот метод обладает потенциалом для решения проблемы, так называемой BCI неграмотности, когда пользователи не в состоянии успешно управлять системой. Максимальная длительность одной классификации может доходить до 16 секунд, зато абсолютно все испытуемые были в состоянии успешно управлять этим интерфейсом.