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SIGNAL PROCESSING TECHNIQUES FOR BETTER PERFORMANCE IN SSVEP FOR BCI

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Abstract: In particular for a spelling programme application, this research offers an optimisation technique for steady state visual evoked potential (SSVEP)-based brain computer interface (BCI). Stimulator, signal processing, and application (spelling programme) are the minimum number of components required to construct a comprehensive BCI application in this application. To achieve the best performance, the three components should ideally operate on independent processing units. However, combining those three parts into a single computer system has other benefits, such as improving concentration and simplifying system setup.

The spelling system and the jerky animation are the two key components that require optimisation. We will concentrate on the display driver technology and programming factors while optimising the flickering animation. The layout and representation of the letter matrix will be the main areas of emphasis for spelling system optimisation. We put our program's frequency range, frequency resolution, and frequency stability to the test across many computers.

Conclusion: Using a computer monitor as the stimulator, it can be concluded that, regardless of the software technology used (DirectX or OpenGL), the maximum synthesizable stimulator frequency is always half of its minimum refresh-rate. With a frequency resolution of 0.11 Hz, the highest synthesizable frequency of up to 30 Hz is attained. 106 people participated in our system testing at CeBIT 2008 in Hannover, Germany. The spelling system's average accuracy is 92.5%. Therefore, without substantial expert assistance or pricy hardware, the optimisation approach outlined here resulted in a stable and dependable system that performed well across the majority of subjects.

I. INTRODUCTION

A computer system with three components has additional benefits. The subject can focus more easily and the system configuration is made simpler by combining the stimulator—a flashing light—and the application (a spelling programme) on the same display or screen. These benefits are crucial since end users need a BCI that doesn't call for complicated hardware (like specialised LED boards or separate computing systems) or specialised assistance (like locating functional SSVEP frequencies or customising the system for each user). The following outline will show how this paper will be presented. The software architecture will be introduced first, and then its optimisation algorithms. The results of the software analysis will then be shown and discussed.

Systems called brain-computer interfaces (BCIs) are made to let people control devices without using the brain's typical neural pathways for output [1, 2]. Using specific digital signal processing (DSP) methods, brain signals—typically nonelectrical signals from the surface of the scalp (EEG activity)—are categorised and then converted into commands. A specific stimulator is needed to enable a signal processing system to recognise particular aspects of the brain signals in the cue-based BCI system, for example, steady state visual evoked potential (SSVEP)-based BCI.

The frequency of the evoked potentials in an SSVEP-based BCI correspond to the stimuli, which are typically induced by flashing light [3]. The DSP algorithm converts the frequency responses into instructions for the cursor movement and character/letter selection in the spelling programme application. The issue arises when a full BCI application, including a stimulator, signal processing, and application (a spelling programme), is implemented using general purpose computers, such as laptops. To achieve the best performance, the three components should ideally operate on independent processing units.

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II. METHODOLOGY

A. Software Architecture:

The following illustration shows the three elements needed to run an SSVEP-based BCI system in a spelling programme application:

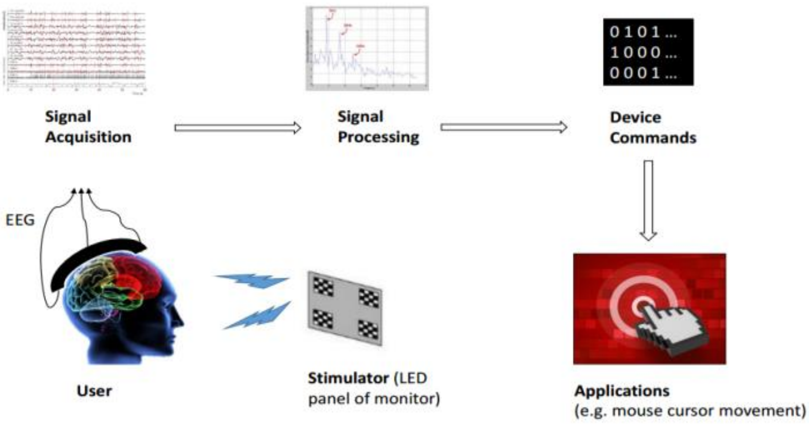

Fig 1: ssvep based bci system software

Of course, a fourth element is needed for any BCI, which are sensors to gather the brain signal [1], but these are not altered in this study and are not further discussed here. The heart of the signal processing unit in this work was a spatial filter termed Minimum Energy Combination that was reported in [4]. In this paper, we concentrate on stimulator and spelling programme optimisation. We developed two programmes that cooperated and were connected via TCP/IP socket in order to combine those three components on a single machine. The first programme, referred to as the Display Programme, is in charge of showing flickering animation to the user as a stimulant, as well as the letter matrix for the spelling programme and visual feedback. The Signal Processing Programme, the second programme, is in charge of signal acquisition, feature extraction and categorization, and command generation. Through a network connection, commands generated by the second programme will be transferred to the first programme. The architecture is shown in the diagram below.

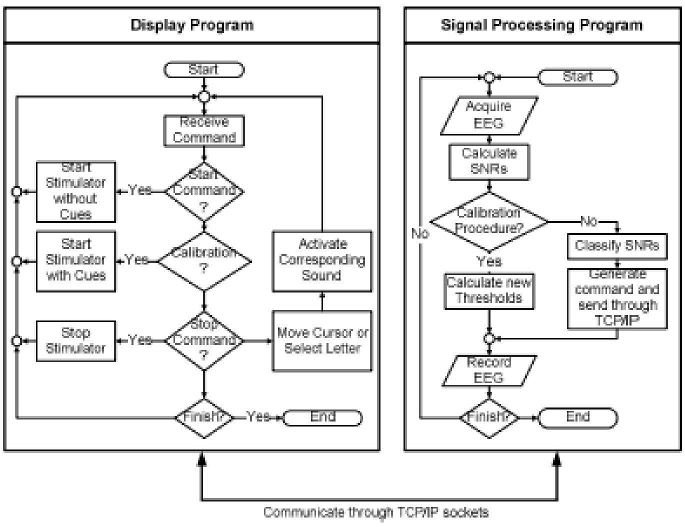

Figure 2 shows the three elements—a stimulator, a signal processing unit, and the spelling program—necessary for the operation of an SSVEP-based BCI system in a spelling programme application.

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B. Optimization Strategies:

The spelling system and the flickering animation are the two key components of the Display Programme that need to be optimised. Following is how the spelling system operates: • We offer a matrix of alphabetical letters along with a moving cursor inside of it. In accordance with the command deciphered by the signal processing programme from the user's EEG signals, this cursor can be moved upward, downward, leftward, or rightward. • The user must focus their sight on the relevant stimulus while choosing a letter to make a word. The letter at the cursor point will be chosen and displayed on the proper position if the Signal Processing Programme is able to recognise this purpose. In this manner, the combination of the chosen letters will result in a word or phrase. With the labels UP, DOWN, LEFT, RIGHT, and SELECT, we generate five flickering boxes on the monitor screen for this function.

The stimulator itself is the next component that requires optimisation. 224 animations with plain texture will elicit a better SSVEP reaction than animations with checkerboard texture, according to our prior research [6]. For the stimulator, we therefore employ a black-and-white animation with a simple texture. We created our programme using the following strategies to produce robust and high resolution flickering frequencies:

• There are five flickering boxes, each with its own thread and timer. We utilise a high resolution timer called Multimedia Timer, which has resolution down to 1ms, because the programme runs on the Windows platform. The timer intervals are computed using the formula below: Interval is equal to 1/(2*fLed)(1), where fLed is the animation's flickering frequency.

• We establish the process with high priority above all other Windows processes, synchronising all of those threads in a single process. In order to use the first CPU's core and give the second core to the signal processing programme, we also add CPU's mask-affinity to this process.

• DirectX 9.0 and OpenGL 2.0, two graphics display technologies, are used and contrasted. These technologies enable us to utilise the graphics card to its fullest potential, greatly enhancing the performance of our programme.

• We utilised the QGraphics Framework from QT when creating programmes using the OpenGL methodology [7]. The QGraphicsView class was then optimised with the following variables:

- ScrollBarAlwaysOff is the scroll bar's policy.
- Interactive events do not interact with one another in the GUI.
- CacheBackground CacheMode

Here is a screenshot of our spelling application's SSVEP-based BCI.

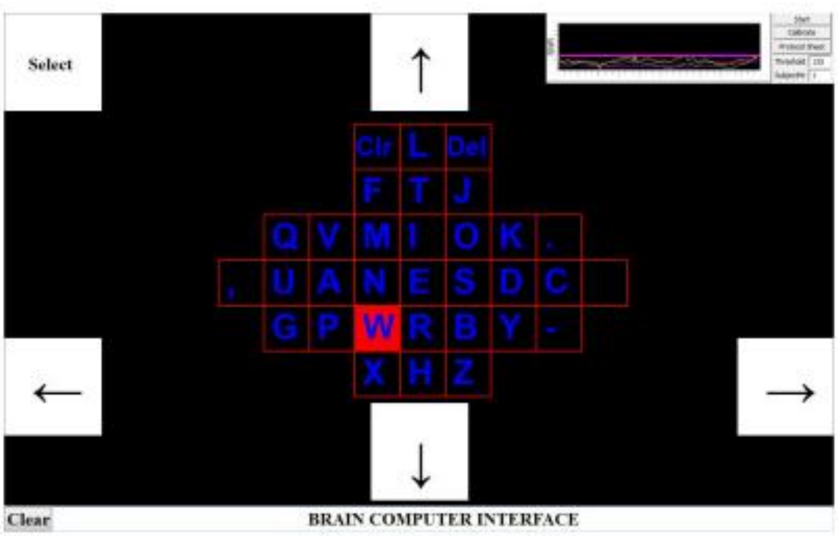

Fig 3: Integrated SSVEP-based BCI for spelling application.

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CONCLUSION

A spelling programme application's optimisation technique for the Bremen SSVEP-Based BCI has been described, and the system's subsequent performance has been assessed. The display performance of the stimulator and the speller programme are the main targets of the optimisation strategy in this study. Utilising cutting-edge graphics driver technology (DirectX and OpenGL), optimising the multi-thread capability of a two core processor, employing a high resolution timer (Windows Multimedia Timer), and choosing a computer with a high CPU rating are how we sum up the optimisation method. However, external factors such as light reflection and interference will also affect the overall performance of the spelling system using SSVEP-Based BCI. Future work should address these two concerns, and try to further improve SSVEP BCI performance while minimizing the needs for expert help, external LEDs, or expensive hardware.

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