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Brain Controlled Chess Based on Virtual Reality Control for Paralyzed Patients

[1]Sindhura Rao, [2]Ashwini S, [3]Kusuma Mohanchandra
[1][2][3]Department of Computer Science & Engineering, Dayananda Sagar College of Engineering, Bangalore

***Abstract*— In this paper, we introduce a game in which the player plays chess by using a brain-computer interface (BCI). The BCI analyzes the steady-state visual evoked potential (SSVEP) responses recorded with electroencephalography (EEG) on the player's scalp. The single three command control game is specifically designed around an SSVEP-BCI and validated in several EEG setups while using a neurosky headset. As a final step in the validation of the game, a random experiment on a broad audience was conducted with the Neurosky headset in a real-world setting.**

***Index Terms*— Brain Computer Interface (BCI), Games, Human Computer Interaction, Electroencephalography (EEG), Steady-State Visual Evoked Potentials (SSVEPs).**

I. INTRODUCTION

In recent years, with the emergence of elasticity (flexibility) in optical networks, the next-generation elastic optical networks (EONs) are able to (i) provision an increased capacity allocation flexibility to the heterogeneous demands by using multiple subcarriers, and (ii) create wider channels based on the demand(s) owing to the aggregation of spectrum units which are referred to as 'frequency slots (FSs)' [1, 2]. Another important feature of the EONs includes the use of various modulation formats (MFs) which differ in both, spectral-efficiency (SE) and transmission reach (TR) [3]. A Brain-Computer Interface (BCI) allows controlling a machine or software through the brain signals without the need for muscular activity. Research on BCIs started in the late 1970s at the California University, Los Angeles (UCLA) under a grant from the NSF, followed by DARPA contract.

BCIs are now one of the most successful engineering applications of the neurosciences as they significantly improve the life quality of individuals who suffer from severe physical disabilities (amyotrophic lateral sclerosis, stroke, brain/spinal cord injury, cerebral palsy, muscular dystrophy, etc.). BCIs reduce the time elapsed between deciding to move the mouse, moving it, and the cursor moving. The lag is small but makes a huge difference to some time-sensitive applications (military uses, gaming software). A BCI can know what one thinks before one does. They identify the electrical neural patterns as a thought - before it has fully manifested into a conscious feeling/command. At the same time, these BCIs mostly rely on conventional electroencephalography (EEG) equipment, which requires specific skills (i.e., positioning the cap, application of conductive gel to the electrodes, verifying the signal quality, etc.), making an all too cumbersome and time-consuming experience for the average user.

BCI systems based on visual evoked potentials (VEP) are currently the fastest method to establish non-invasive BCI control. Recently, the focus shift is towards a new group of potential users, i.e., the general population. Gaming enthusiasts are target users, as they are a very lucrative endeavor, willing to learn a new modality if it could prove advantageous. However, the new trend towards more fine-grained control, smooth, application-specific interpretation of BCI control signals, precision timing, and a movement beyond feasibility tests needs a greater understanding of the domain. Emphasis is on the role BCI can play in improving the game experience. Research groups are also tentatively testing whether BCI is feasible in real-time applications. Future BCI's will probably deal with the natural behavior of users, function in coordination with different modalities, many users, diverse contexts, and numerous mental tasks and signal types.

II. OBJECTIVE

The aim of this project is the design of a low-cost, user-friendly and efficient BCI-controlled chess game. Gaming is very popular among children and adolescents and has increased drastically over the last decade. The game holds great potential for people who are paralyzed or otherwise unable to use their hands and is also applicable for people whose hands are just otherwise occupied.

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III. THEORY AND METHODOLOGY

Almost all existing BCI designs targeted at disabled individuals. Hence most BCI applications aim at providing prosthesis for rehabilitation purposes. As the cost and effort to use BCIs decline, a brain-computer interface may also target healthy person. Games may be used to exploit BCI uses for healthy people. The chess game is an application that is also of interest for healthy individuals. The primary objective is the design of a BCI-controlled chess game: How can a brain-computer interface be designed to control chess software? To determine the use of the designed system, the following questions should be addressed:

- How much time does it take to make a move?
- How efficiently can moves be communicated?

3.1. The Neurosky Headset

The brain-computer interface is a direct communication channel between a biosensor based brain signal processing unit and an external device. BCI systems can be divided into two main groups according to the measurement of bioelectrical signals. In the case of EEG, where biosensors are directly placed into the brain, we are talking about invasive BCI, otherwise, if the electrodes are placed somewhere on the head, for example on the forehead, we are talking about non-invasive BCI. Due to the dangers of an invasive process, non-invasive BCI systems are preferred.

EEG is a medical technique that is used to measure brain waves. This technology is generally used in medical science where neurologists use EEG to diagnose cases of epilepsy, among other medical issues such as being comatose and having sleep disorders. The way an EEG works is through the reading and recording of brain waves. Brain waves are tiny electrical waves that are released when a neuron sends an order from one neuron to the next. These small electrical waves, come together and form a more complex brain wave pattern.

Figure 1. A Neurosky Headset and a user wearing the Neurosky Headset

The NeuroSky Mindwave is a piece of equipment that was created and released by NeuroSky, Inc. for the purpose of reading the user's mind waves. It makes use of EEG, which is the recording of electrical activity along the scalp [1]. The design of the NeuroSky Mindwave mainly consists of three main parts as seen in Figure 1. First of all is the headband which can be customized according to each user's preferences as per their comfort. The second part consists of the Sensor Arm and Tip which serve as the sensor through which the Mindwave could read the user's brain activity. It is important to place the tip on the user's forehead without any interference from factors such as hair to give out the most accurate readings it is capable of. Lastly, would be the Ear Loop with an Ear Clip attached to it. The ear clip is supposed to be placed on the user's Lobule.This acts as a ground, and a sensor to filter out the extra signals that the body and the surrounding area gives out for the machine to give out more accurate data free from noise. All three parts work in tandem to give the user the best experience they can have while using this product and being connected to the computer wirelessly through the use of a Bluetooth dongle. The NeuroSky Mindwave serve as an EEG through the use of a dry electrode to take recordings of the brain and pass the result in an application that uses the data read from it as it wishes. It is processed by an embedded chip that outputs two main categories, the user's attention, and meditation states. Due to the use of a dry electrode instead of silicon or gel-based electrodes, one can use it despite the interference of hair, unlike that of the EMOTIV EPOC where it would not be able to gather data due to hair interference. The Mindwave Manager is a program that allows the computer to be paired up with a NeuroSky unit through the given Bluetooth dongle. It is to be noted that only one Mindwave unit can be paired with a computer at one time. Meaning the computer can only retrieve data from that one unit at one time. Processing is a program created by Ben Fry and Casey Reas in the spring of 2001 [2]. This program is popular for its ability to use different libraries while able to read data straight out from a serial port. This is used by this project to directly communicate and receive the data from the NeuroSky Mindwave as the data is sent through the Bluetooth dongle attached to the computer.

IV. EXPERIMENT AND RESULTS

Information process flow of the BCI system is built up by four main components. Figure 2 shows the architecture of the BCI system process flow.

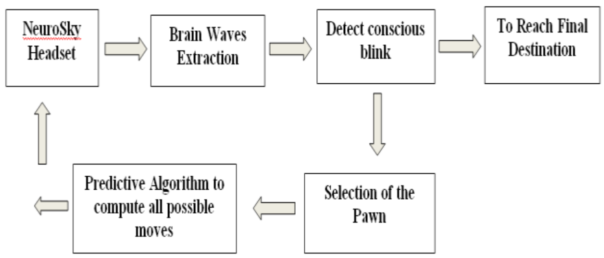

Figure 2. Architecture of the BCI for Game Control

The Mind Wave headset gathers the brainwave signals using two electrodes touching the skin in two different locations, behind the ear, and in the forehead, and processes it to isolate individual signals. The brain signals can be identified by eight different bands of frequencies as Delta (0.5 – 4 Hz), Theta (4 - 8Hz), Alpha (8 – 16 Hz), Beta (16 – 31Hz) and Gamma (31 – 62Hz) [3]. The headset can also detect the blinks. The EEG signal is shown in figure 3. It was observed that EEG signal obtained from conscious eye blink produces clearer signals with larger amplitude. The eye blinks are often identified by setting a threshold and classifying as eye blinks for all activity exceeding the threshold value. There is variability in the amplitude of the EEG signals across different individuals.

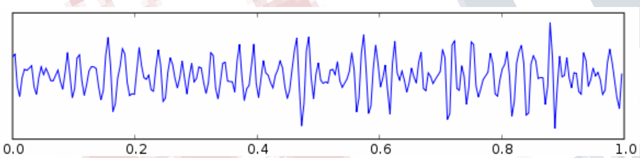

Figure 3: EEG signals

The architecture uses a multithreaded game loop wherein the main thread is responsible for the game, and the BCI thread is responsible for dealing with EEG brain waves. The main thread is based on the single game loop, with an additional phase responsible for gathering messages from the other thread.

Figure 4: The layout of the chessboard

The player is positioned before an 8*8 chessboard shown in figure 4. Team White begins the game as per rules. Hence, the rows containing white pawns will be marked to select the pawn. Each row containing the white pawns is sequentially highlighted, and the player may choose the row via a conscious blink when the row desired by him/her is highlighted. The software shall distinguish this conscious blink from involuntary blink and interpret this conscious blink as a “select “command.

For faster results, the Divide and Conquer approach is used. The next step is to select either the left half or the right half of the blocks from the selected row. Again the user consciously blinks when the desired half is highlighted and this procedure is repeated until the desired pawn is selected. The same procedure is repeated to select the target block. But only the blocks that can be called feasible destinations as per the rules of chess are computed via an algorithm and these blocks are now highlighted so that the player may select the desired destination for the pawn selected. By this predictive algorithm, we can achieve faster results.

Algorithm for rook movement:

Begin:

Object[0]= Vertical_check(intx,int y) ; // x and y are coordinates of block of matrix

Object[1]=Horizontal_check(intx,int y); //Objects store results of the check

Object[2]=Diagonal_check(intx,int y);

ComputePossibleDestinationBlocks(Object[]);

End

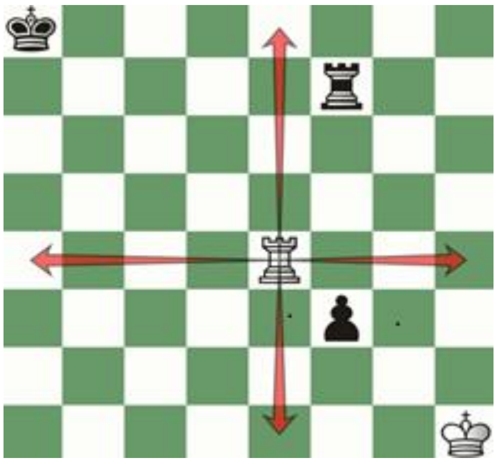

Figure 5. Possible movements for rook pawn

The game screen depicts a typical 8*8 chessboard alternating blocks of green and white color with two teams. Pawns of one team are colored white and the other black. Each team begins with 16 pawns, namely, one king, one queen, two each of rooks, bishops, and horses and eight soldiers. The white team makes its first move through selecting the desired pawn to be moved, which is calculated via capturing of brain signals. The first selection involves selecting one of the two rows where the cursor repeatedly flickers until a row is selected. Once the desired row is selected, the left half or right half must be determined. This repeated division continues until the desired pawn is selected.

The next step uses an algorithm to predict the possible destination blocks for the selected pawn keeping in mind the rules of chess and the positions of the pawns at that instant of time in the gameplay. Again repeated division of the chessboard is done till the desired location of destination for the selected pawn is obtained. The same procedure applies for the black team to make its move, and the game continues until one of them wins by killing the other team's king or force quit via a button.

Exceptions in the game: A check occurs when one of the team makes a move that endangers its opponent's king. A checkmate is when the opponent is left with no moves to save its king. If a pawn occupies the same block as its opponent's pawn abiding by the rules of chess, it is a hit. When the king becomes the lone survivor, the team is left with 16 moves to settle for a draw. An undo button is supported to revert an undesired move which increases the accuracy of the game.

V. CONCLUSION

The main goal of this work is to research the potential of the use of EEG devices in conjunction with the games and new possibilities of human-computer interaction with a new form of interaction using the brain wave. The tests and analysis of the game gave valuable insight information for further investigation and development of new strategies for the use of BCI in games. We are able to gather data from players using our simulation set-up. We conclude that the presence of distraction does not necessarily contribute to the increase of the beta waves. It all depends on the person if he or she reinforces their focus and concentration to do the job at hand or relax their concentration. It can also be said that people with a steadier concentration can have better overall results rather than those whose concentration have large variations. Future work will concentrate on providing a game of cognitive behavior during the game and also further development of the framework to identify more brain patterns. Also, future work will try to use the BCI with a machine learning algorithm and also create an Android app for the game.

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