

# USING BRAIN-COMPUTER INTERFACE TECHNOLOGY FOR MODELING 3D OBJECTS IN BLENDER SOFTWARE

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**Abstract:** *Computer 3D modeling has primarily relied on the Windows, Icons, Menus, Pointer (WIMP) interface in which user input is in form of pointer movements and keystrokes, since its beginning. The brain-computer interface (BCI) is a technology which allows users to take action in computer by using their brain signals. This paper presents the usage of EMOTIV EPOC+ Neuroheadset in Blender software for executing specific Blender's functions for editing 3D objects. The purpose of this paper is to briefly, yet illustratively, present the application of EMOTIV EPOC+ Neuroheadset in an interesting application in Blender software for the editing of 3D objects.*

**Keywords:** *BCI, EMOTIV EPOC+ Neuroheadset, Blender, 3D modeling*

## 1. Introduction

3D modeling is a process of creation and modification of three-dimensional objects using a specialized computer program that provides a set of necessary tools for user. 3D modeling usually starts with basic shapes (primitives) such as cubes, spheres, torus and others. These shapes are then modified by different functions provided in software. The user activates these function usually by pressing combination of keys on keyboard or by selecting them from the user interface. Nowadays, there are many powerful 3D modeling software which allows to create 3D assets, animations, special effects and render images. The most popular paid applications are Autodesk Maya, Autodesk 3ds Max and Cinema 4D. There are also many free applications available but the most popular one is called Blender.

Blender is a free open-source 3D computer graphics software toolset. It is written in C, C++ and Python programming languages. Blender Foundation is a non-profit organization that is responsible for the Blender development. Blender is also developed by the community which creates additional plugins written in Python (called add-ons). Add-ons add new or improved functionality to Blender. Blender has recently gained a big financial support by Epic Games, Nvidia or Intel due to the creation of Blender Development Fund. It allowed Blender Foundation to recruit new team members and in the result to develop Blender faster.

The main features included in Blender are: 3D modeling, texturing, animating and rendering. It mainly relies on Windows, Icons, Menus, Pointer (WIMP) interface which forces users to memorize multiple hotkeys or use the graphic icon to finish the action. Because of that the user's capabilities and performance in modeling process are limited.

User interaction with computer should include the human-human interaction (HHI) aspects in the interface [1]. HHI involves the simultaneous application and perception of behavioral signals such as gestures, speaking or moving [2]. However, there have already been many interfaces that took this approach in order to combine speech with gesture, speech with mouse or speech with touch input [3–5]. A very promising technology is developing nowadays. It is called Brain-Computer Interface (BCI). Because of BCIs' big possibilities, the usage of connection between human brain and a computer might have a great impact on a way the people communicate with a computer [1]. It can find an application in 3D modeling but also in many other areas.

BCI is a field of research that is developed to collect human brainwaves and relate patterns in brain signals to the users' thoughts and intentions via electroencephalography (EEG). BCI is also known as Brain Machine Interface (BMI) or sometimes known as Direct Neural Interface [6]. BCI appears in many areas including control of various software applications (including video games, web browsers or typewriters), modern smart home applications or environment control, but mainly targets disabled people (wheelchairs, neural prosthetics, robotic arms) [7–11]. The big BCI's advantage is its non-invasive nature [12].

BCI uses electroencephalography which is a way to record and analyse human brainwaves. Brain waves are divided into groups such as Gamma, Beta, Alpha, Mu, Theta, Delta. As shown in Table 1, each of the brain waves has a different frequency and function [13].

**Tab. 1.** Brainwave rhythms and their functions

Rhythm (frequency)	Function
Gamma (>30 Hz)	Awake with large brain activity
Beta (12 – 28 Hz)	Awake with mental activity
SMR (13 – 15 Hz)	Awake with physical activity
Alpha (8 – 12 Hz)	Awake and resting

Rhythm (frequency)	Function
Mu (7 – 11 Hz)	Awake and resting
Theta (4 – 7 Hz)	Sleeping
Delta (1 – 3 Hz)	Deep sleep

EEG is not the only input that can be used to communicate with a computer. Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles.

There are many low cost, non-invasive EEG devices available now. The research has been performed using EPOC+ Neuroheadset developed by EMOTIV (According to [14] the best commercial neuroheadset in terms of usability). The use of EMOTIV EPOC+ Neuroheadset involves using EEG signals simultaneously. Every user has individual thought pattern when performing the same task. All thoughts can be assigned to a specific Blender functions. The user-specific signals are converted into intended operations performed on editing object. Those operations include, moving, scaling, rotating objects or extruding.

This paper describes the research process followed by software and overall system used in the study. It presents measurements results followed by implementation concept, summarize tests and conclusions at the end.

## 2. Research Methodology

In the study carried out electrical signals based on user's brain activity were used, i.e. electroencephalography (EEG), and facial muscles for interfacing with the EPOC Control Panel suites which later are used to work with Blender.

First of all the EMOTIV EPOC+ Neuroheadset had to be prepared to be ready to work. The battery had to be charged. It took about 20 minutes to charge the headset. In order to acquire accurate signal the sensors had to be hydrated using saline solution. After that, the sensors were installed in headset. Then the headset were fitted on the head. EMOTIV EPOC+ Neuroheadset uses Bluetooth connection to communicate with a computer. The USB Bluetooth receiver was plugged in the USB port. Secondly, the EPOC Control Panel application was opened to check contact quality of each sensor. The sensor electrode figures correspond to the quality of contact with a skin: green, yellow, orange, red and black indicating high to low quality (Fig. 1). Figure 1 also shows the intermediate states showing the lack of correlation between the electrode and the scalp at the calibration stage.

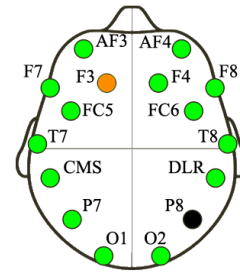


Fig. 1. Sensors distribution on human head

The third step was to train some action to manipulate the virtual 3D cube. Starting with a neutral state where user had to relax and clear his thoughts. Then, the first action was selected (how the cube should behave) and training began. During a training user tried to imagine some things (for example moving the cube to left). After a training the attempt of moving the cube to the left was done (Fig. 2). The goal was to achieve all four levels in order to manipulate the cube in four possible ways. During the whole research session all brain waves were monitored via EMOTIV Xavier TestBench (Fig. 3).

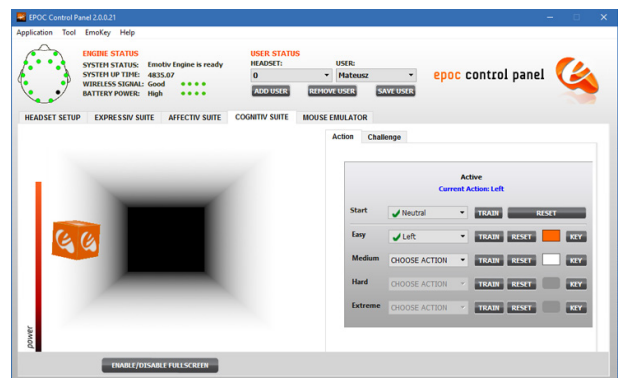


Fig. 2. Interface of EPOC Control Panel application

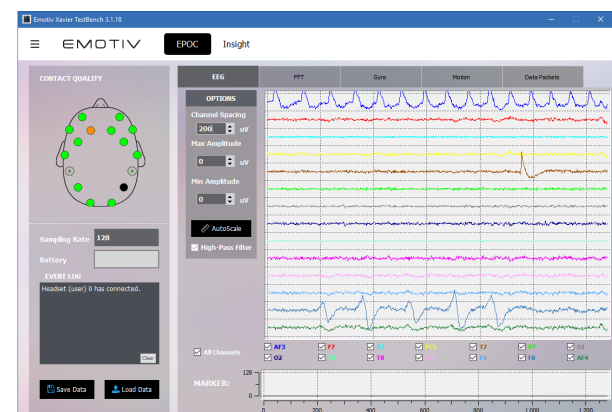


Fig. 3. Interface of EMOTIV Xavier TestBench application

### 3. Measuring Device

The EMOTIV EPOC+ Neuroheadset is equipped with 14 biopotential sensors with gold plated connectors. These sensors are optimally positioned on the head to record signal from many brain areas. The sensors locations are: AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2. The communication between EMOTIV EPOC+ Neuroheadset and computer is based on wireless Bluetooth 2.4 GHz connection via USB Bluetooth receiver which does not require custom drivers [15]. The headset is powered by rechargeable Lithium Polymer 640 mAh battery. It can capture brain activity up to 12 hours. EMOTIV EPOC+ Neuroheadset is equipped with 3-axis accelerometer and 3-axis magnetometer. It gives users total range of motion. The EMOTIV EPOC+ Neuroheadset has an inbuilt EEG is filtered by the EPOC+ hardware with a fifth order digital Sinc filter using bandpass of 0.16–43 Hz and notch at 50 Hz and 60 Hz. The sampling rate of the headset is 128 Hz [16]. It is supported on Windows, MAC, iOS and Android. It recognizes facial expressions like blink, wink, surprise, smile and more. It also measures emotions like excitement, stress, focus or relaxation [17].



Fig. 4. EMOTIV EPOC+ Neuroheadset [17]

### 4. Measurement Results

The various results recorded from an EEG-based cognitive BCI experiment designed to convert human thoughts on specific virtual cube manipulation actions via electroencephalography are presented and described in this section. The results shown here are for one subject (an author).

The first part of an experiment includes training of neutral state of a brain and training of four different actions performed on the virtual cube. The whole process is supported by monitoring brain activity in real time represented by chart records.

During neutral state training the thoughts were cleared out and big variations were not noticed on the EMOTIV Xavier TestBench charts. All of 14 charts were oscillating around zero.

During the second training (Easy) the selected action was moving the cube to the right. In the result, minor variations appeared on charts in many areas. The most significant changes were detected in AF3, AF4, F7 and F8 brain areas as shown in Fig. 3. Attempt of moving the cube to the right was successful but some problems appeared. The cube was not fully controllable. It was performing chosen action in random moments. The cube was not fully controllable because of many thoughts in a brain which were interfering the signal. It took about 5 minutes to start controlling the cube. It was achieved by focusing more on the cube and trying to stay calm.

After training another action (moving cube to the left) the level of the complexity of controlling the cube increased. Many unintended actions i.e. random movement to the right or to the left appeared. The time of the adaptation to fully control the cube increased to about 8 minutes.

The third action (moving up the cube) was partly achieved. The level of complexity and the time needed to adapt to control the cube raised to 10 minutes. The cube was partly controllable. Many unintended actions appeared. The full control was not achieved due to limited battery charge percentage and available laboratory session time.

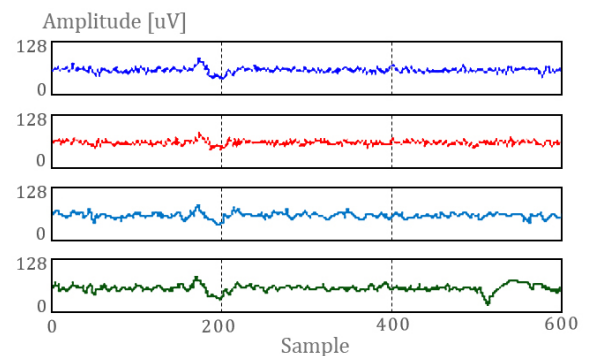


Fig. 5. EEG signal from (respectively) AF3, AF4, F7 and F8 sensors

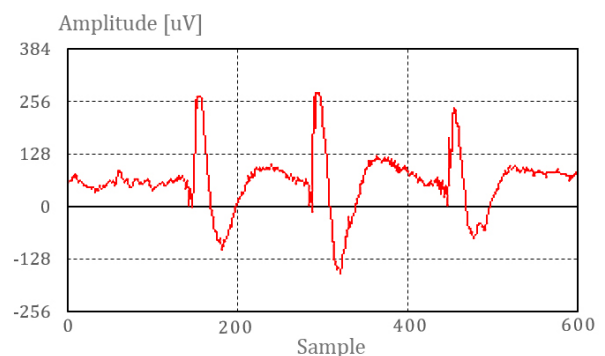
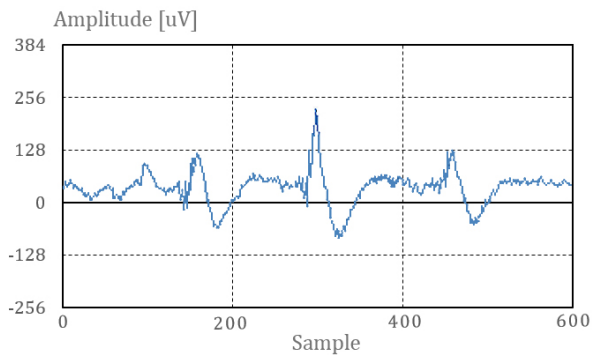


Fig. 6. EEG signal as an artifacts from F7 sensor



**Fig. 7.** EEG signal as an artifacts from F8 sensor

The second experiment concerns the usage of facial muscles. The one difference between the first and the second experiment is that facial expressions were recorded during a training instead of thought pattern.

The significant changes have been detected in some areas corresponding to a specific face muscles movements. Fig. 6 shows signal strength from F7 and F8 sensors after rising eyebrows. The signal strength is very big comparing to the EEG thoughts signal. It appears as a artifacts on charts. After training the first action, the cube moved to the right instantly with a maximum power. All of four available levels (Easy, Medium, Hard and Extreme) were achieved in approximately 7 minutes. Due to that the virtual cube could be manipulated in four possible ways by performing assigned face action (Table 2).

**Tab. 2.** Mapping of face actions used cube manipulation

Cube manipulation	Face action
moving right	Close right eye
moving left	Close left eye
moving up	Raise eyebrows
rotate	Clench teeth

EEG brain thoughts training took more time than facial expression training to fully control the cube and the complexity of manipulating it was much higher.

## 5. Implementation Concept

The implementation concept involves connecting corresponding user thoughts and facial movements with a specific Blender functions. The processes that would allow this to happen are training though patterns/facial expression and assigning them to a specific key/keystroke. It could be done by using some of EMOTIV applications. EMOTIV APIs are used as a connector between user and Blender. The functions used in this study are EPOC Control Panel and EMOTIV Xavier EmoKey.

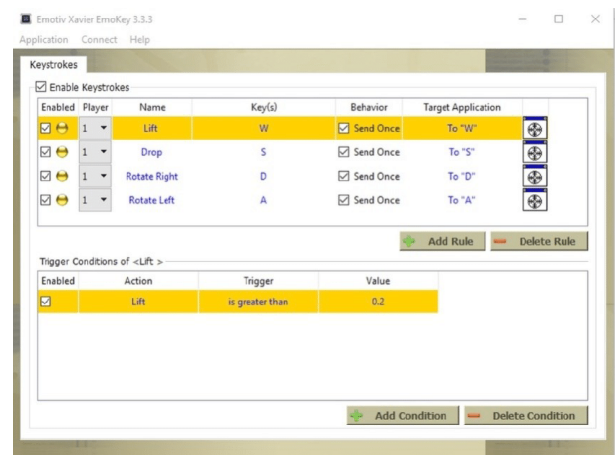
The EPOC Control Panel is used as a training platform in which user is able to configure the headset in a desired way. User can display there the sensors' signal quality or battery power. EPOC Control Panel consist of Expressive suite, Affective suite, Cognitiv

suite and Mouse emulator. The most significant are Cognitiv and Expressive suites.

The Cognitiv suite is responsible for acquiring EEG signal and associating it with a specific action. During the cognitive training, the user has to imagine manipulating a cube in the virtual environment (see Fig. 2).

The expressive suite uses signals that are generated from the movement of facial muscles. It offers assigning specific keys/strings into seven different facial expressions (look left/right, blink, left wink, right wink, raise brow, clench teeth, smile). It is possible to adjust the sensitivity of triggering actions assigned to specific facial expression.

Another used function is EMOTIV Xavier EmoKey. EmoKey is a background process that runs behind applications. It is used to emulate keys or keystrokes which are assigned to a specific user's though or facial expression via user interface. During the assignment of EEG signals it is possible to set specific conditions which defines when the specific action will be triggered. These conditions are: 'greater than', 'equal to', 'lesser than', and 'occurs'. It enables user to calibrate the strength of signal which is required to perform an action. There is also a possibility to choose the window of the application in which the key will be emulated. Therefore, EMOTIV Xavier EmoKey can be a user's configuration tool which allows to assign specific EEG signals to specific keys that will activate intended functions in Blender.



**Fig. 8.** EMOTIV Xavier EmoKey application interface [18]

## 6. Tests

Keystrokes showed in Table 3 are used to execute specific functions in Blender. Every action showed in Table 3 was assigned to a specific key/keystroke during the training session described in "Measurement results" section. Six function in total were assigned to specific actions. Two of them use EEG signal and four of them use signal generated by facial expressions. As shown in Fig.5. every action performed by user is detected by BCI system and processed by EMOTIV APIs. The output of this process is in form of an emulated key/keystroke which next is used to execute specific function in Blender.

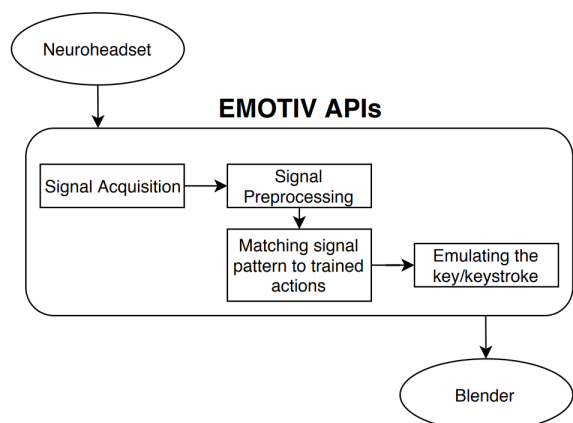
As shown in Fig. 6 the Rotate function is executed by pressing “R” key on the keyboard. In order to press “R” without using a keyboard the EPOC Control Panel Cognitiv Suite was used. User tried to imagine the rotation of an object just like during the training. The “Rotate” function was then executed in Blender without any physical interaction with a keyboard or a mouse. Then it was possible to specify the rotation axis (X,Y,Z) and the angle of rotation. The rotation angle could be set using the mouse movement or by typing the specific value using keyboard.

The “Scale” function was assigned to facial expression action. After rising eyebrows the scale function was executed in Blender. The scale value could be specified by typing a value on a keyboard or by moving a mouse.

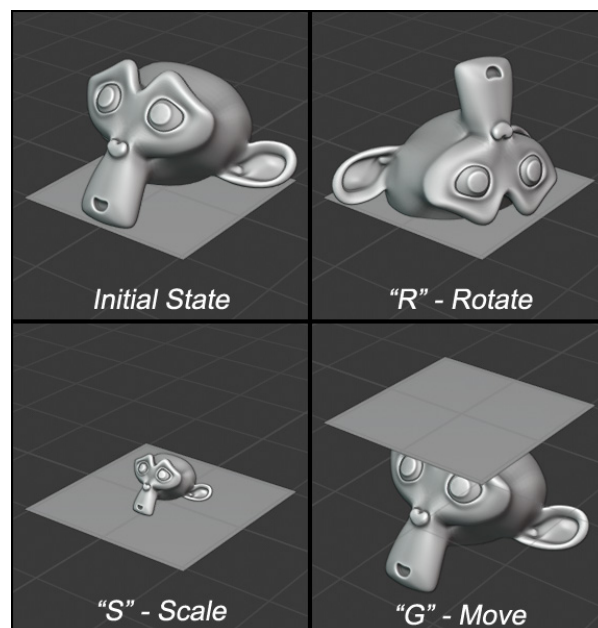
The one problem occurred when using the neuroheadset. At the beginning of the laboratory session the neuroheadset was not fully charged. The battery run out after 1 hour and 40 minutes of working. EMOTIV EPOC+ Neuroheadset was less response for about ten to fifteen minutes before the battery run out. The battery power status was displayed as “Critical” in the EPOC Control Panel. It has affected the attempts of manipulating the cube in EPOC Control Panel Congitiv suite i.e. after completing the training on any level, the virtual cube did not perform any action. The signal variations displayed on charts in EMOTIV Xavier Test-Bench were a lot weaker than before. The variation were detected only after facial muscles movement.

**Tab. 3.** Sample mapping of keystrokes using EMOTIV Xavier EmoKey

Function	Action	Key/Keystroke
Grab	Though 1 (Easy)	G
Rotate	Though 2 (Medium)	R
Scale	Raise eyebrows	S
Extrude	Clench teeth	E
Undo	Close left eye	CTRL+Z
Redo	Close right eye	SHIFT+CTRL+Z



**Fig. 9.** A process of converting brain signal to emulated key/keystroke



**Fig. 10.** The performed functions on monkey's head model in Blender using emulated keys

## 7. Conclusion

In this paper the BCI-based system is evaluated to be a tool in a 3D modeling process in Blender. However, the presented concept can be used in many other applications. Blender is only one example. Many 3D applications uses WIMP interface based on mouse and keyboard and requires memorizing many keystrokes to perform specific actions just like in Blender. The application of this concept in popular 3D software might have a big influence on the 3D industry and change a way to model 3D objects in many applications.

The research was focused on recording EEG signals and converting them into user-specified actions using EMOTIV EPOC+ Neuroheadset and inbuilt APIs. The processed information is then used to carry out 3D modeling in Blender. Several tests were performed, in order to evaluate the usability of this concept. Tests involved a training of some action to manipulate the virtual 3D cube in EPOC Control Panel using brain signals and facial expressions. After tests it can be concluded that the level of complexity of manipulating the cube increase with the number of trained actions. Controlling the cube by using the facial muscles movement is much more responsive and intuitive for user and also requires less time to train than using brain signals. However, in case of cognitiv control, the number of possible functions that could be assigned to a human thoughts is almost limitless. This is the biggest advantage over the face expressions control.

Nevertheless, the BCI can be used in 3D modeling. The main issue to focus on in the future is to decrease the time needed by user to configure the BCI system and the time needed to adapt to it. The more time user uses the BCI, the more controllable and useful it becomes. The other issue to improve is better rec-

ognition and analysis of thoughts patterns. The more precise study in this field in a future might allow to increase the usability of BCI in 3D modeling but also in many other areas. The development and progress in BCI might be essential in the future for human interaction with the electronic devices. The effect of this might be that people will not need a mouse and keyboard to control the computer. The pace and efficiency of their work will then increase.

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