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CogniDriver

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Abstract

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The aim of the project is to provide an overview of the development of CogniDriver, a 3D mind-controlled car driving game which uses the Emotiv EPOC interface to control the car movement. The headset also allows the activation of various game effects such as raining when the frustration levels are too high or changing the camera view when the player does a left wink.

The Unity game engine has been used while developing the game in order to gain access to an advanced physics engine and to a multi-platform deployment tool.

The results of user testing on 13 participants have shown that although it is more difficult to control the game while in Cognitiv mode, the game appears more challenging and more interactive than a normal Keyboard mode play.

In the conclusions a short overview of the current deficiencies are presented as well as potential for further development.

Supervisor: Toby L. J. Howard

Acknowledgements

I would firstly like to thank my supervisor, Toby Howard, who has provided great advice and support throughout the project.

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Chapter 1

Introduction

1.1 Applications

Using BCI (Brain Computer Interfaces) to control an application is of great use to persons with motor disabilities whose use of keyboard or mouse devices might not be convenient. In addition, BCIs provide a great way to exercising brain functions and improving concentration.

1.2 Aims and objectives

The aim of this project was to learn about the ... and falls of BCIs, how these interact with the computer and reach a conclusion about how they could be used in the future. Because the Emotiv EPOC Control Panel allows only up to 4 actions to be recognised at any one time, the simplest choice of a game was that of a car driving one since you can also observe the car moving in the dictated direction which can ease the activation of an action through the visual feedback.

The key objectives of the project were to:

- Allow the car to move in each one of the four directions: forward, back, left, right through keyboard use;
- Reach access to the interpreted data of the developers' SDK;
- Allow players to train new profiles inside the game;
- Provide an array of cars and colours that the user can select from.

1.3 Report outline

The report begins with describing the used tools and provides some information about the way the brain works in Chapter 2. Next, Chapter 3 describes how the Emotiv EPOC works and how it is organised. In this chapter, the report also contains a quick look over some other applications developed with this technology.

Chapter 4 focuses on the description of the design of this project, while Chapter 5 oversees the implementation details. Chapter 6 reviews the obtained results, while Chapter 7 described the performed testing. Appendix 1 shows the user questionnaire used during the user trials. Finally, Chapter 8 contains the conclusions of this project.

Chapter 2

Background

This chapter aims to provide a general overview of the tools used while building CogniDriver. It also describes some basic concepts about how the brain works which would be useful to know before diving into the description of the headset.

2.1 Development tools

2.1.1 Unity

Unity is a game engine which allows:

- Game deployment on a variety of platforms;
- Easy object importing;
- Object manipulation;
- Scene design;
- Creation of primitive shapes (sphere, cube, etc.);
- Collision detection;
- Automatic object updates;
- Game physics.

I should also highlight some of the reasons why Unity was chosen in favour of other game engines such as UnReal. Unity allows file import by a simple drag-and-drop and it also auto updates the objects if you change the source files using another program (e.g. Paint, Photoshop). The advantages of UnReal over Unity would be better graphics (mainly lighting) and the fact that it can fracture meshes. In terms of scripting, Unity allows development in JavaScript, C# and Boo, while UDK only allows UnrealScript. For CogniDriver, C# has been the scripting language choice, because it allows Object Oriented Programming (OOP) and it is scalable for larger projects.

Unity has been used to create games such as Assassin's Creed Identity, Need for Speed World and Battlestar Galactica Online.

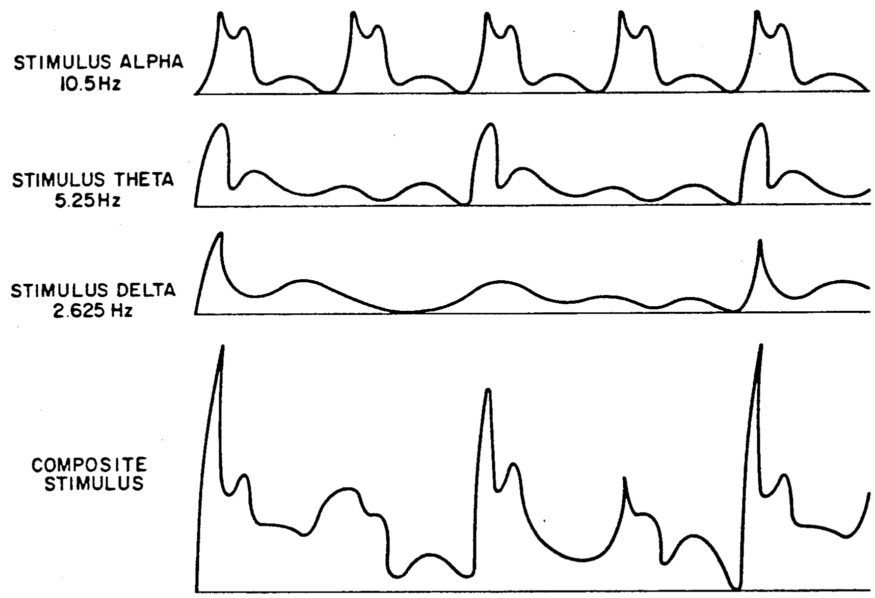


Figure 2.1: A composition of alpha, theta and delta brainwaves. Credit: [Gall, 1992]

2.1.2 Easy Roads 3D

This plugin is available in the Unity asset store. The free version has been used for this project. It allows placing markers through which the road should go, and given a specified width, it approximates corners and builds the rest of the road into a single layer.

2.1.3 Photoshop

A trial version has been used to create some materials and textures such as: skid marks, rain, smoke texture, speedometer, arrows, colours choice. None of these are difficult to create, but I like Photoshop because it is easy to use by both novice and professional users. In addition, the layers allow the user to create many compositions and modify the image at will.

2.2 Electroencephalography (EEG)

The neuron is the core component of the nervous system. More neurons can connect together to form synapses and when one of these cells is excited, an electrical signal is generated. The electrical signals can be amplified and the resulting waveforms, known as brainwaves, can thus be obtained. They can then be used to monitor the brain activity of a person in order to detect abnormalities. In table 2.1, a representation of each type of most common brainwave types is shown, together with the normal activities in which these occur most often.

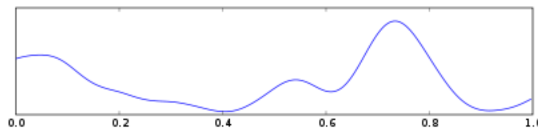
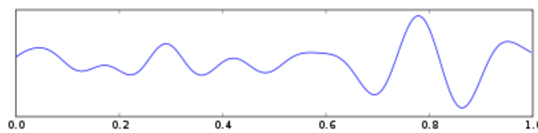
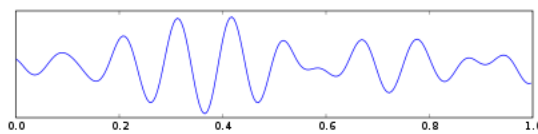
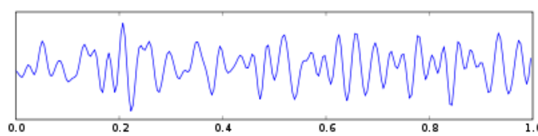
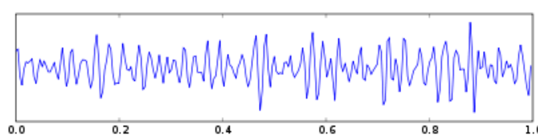
Name	Frequency (Hz)	Occurs in	Image Representation
Delta	<4	deep sleep , unconsciousness, deep anaesthesia, hypoxia	
Theta	4 - 7	stress, unconsciousness, deep relaxation	
Alpha	8 - 15	relaxation	
Beta	16 - 31	conciousness, alertness, thinking, sensory stimulation	
Gamma	32 +	selective attention, human cognition and perceptive activities	

Table 2.1: Information about brainwaves types [Ning-Han Liu and Hsu, 2013]. Image Credit: Hugo Gamboa

Please note that almost always the EEG will display a composition of a set of types at any point in time. One example can be seen in the figure 2.1. Brain Computer Interfaces (BCIs) are a channel of communication between the electroencephalograph (EEG) and the computer.

Chapter 3

Introducing the Emotiv EPOC

3.1 SDK description

The Emotiv EPOC headset is a portable EEG device which consists of 14 sensors that transmit raw EEG data (see figure 3.1 for their positioning) to the computer and 2 reference sensors (CMS - Common Mode Sense and DRL - Driven Right Leg). The CMS sensor is the point on the scalp against which everything else is measured. The DRL sensor provides a feedback signal to cancel common mode noise in the electronics [Emotiv, 2015a, BioSemi, 2015]. See table 3.1 for the meaning of the abbreviations of sensor positions. The raw data gets interpreted and the user gains access to all of the information in one of the following 4 suites: Expressiv, Affectiv, Cognitiv, Mouse Emulator.

Abbreviation	Meaning
A	Ante
F	Frontal
C	Central
P	Parietal
T	Temporal
O	Occipital

Colour code	Meaning
Black	No signal
Red	Very poor signal
Orange	Poor signal
Yellow	Fair signal
Green	Good signal

Table 3.1: Left: Abbreviations for sensor positioning; Right: Sensor contact quality and colour codes

I have been using the developer's SDK, so it is worth highlighting I did not have any access to the raw EEG data.

The battery lasts about 10 to 12 hours. The charging is done via a USB cable.

According to [Adelson, 2011], the data sampling rate is 128Hz. [emo, 2014] states that there may be up to 2 seconds delay from when the data is sent until it is received.

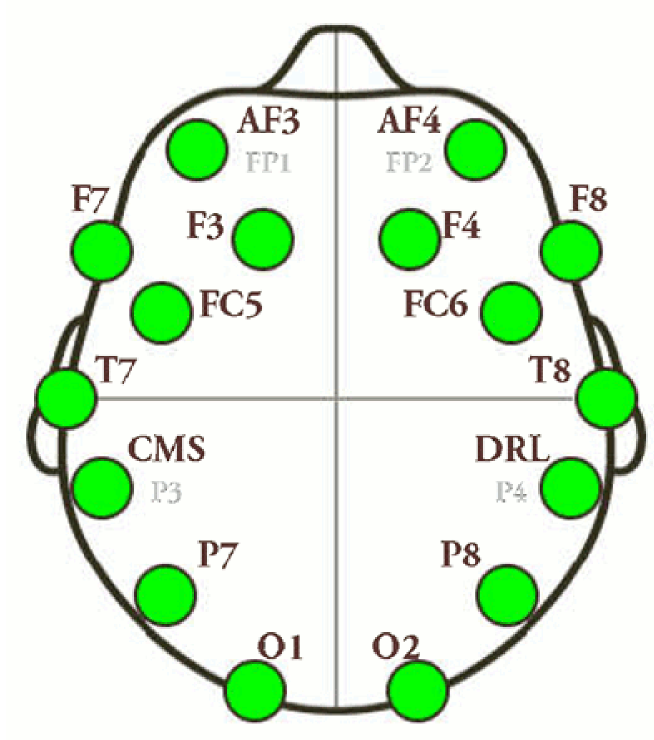


Figure 3.1: Sensor positioning for the Emotiv EPOC. Credit: Emotiv

Expressiv^{TM}Suite

Detects 12 facial expressions:

1. Blink
2. Left wink
3. Right wink
4. Look left
5. Look right
6. Smile
7. Laugh
8. Smirk left
9. Smirk right
10. Raise brow
11. Furrow brow
12. Clench teeth

One thing to note is that if the sensor contact quality is not perfect (all green - see table 3.1), blink and winks might be mistaken; same applies to laughs and smiles. In fact, an ideal signal is obtained when all sensors display green. It is acceptable to have some displaying yellow but anything less than yellow, means data might be unreliable or unavailable.

The API usually gives back data as a `boolean`, but for smile, clench and look left/right, a `float` between 0 and 1 can also be obtained which represents the extent of that expression.

Figure 3.2 shows an image of how the EEG looks like in channels AF3 and AF4 after a blink. See figure for a screenshot of the suite.

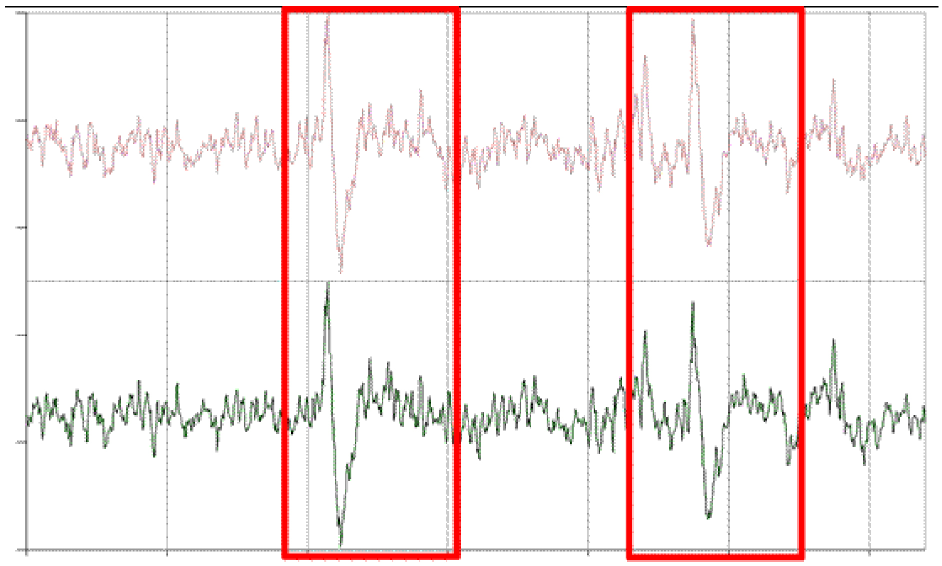


Figure 3.2: AF3 and AF4 channel response to eye blink. Credit: [Adelson, 2011]

Affectiv™Suite

Returns a `float` between 0 and 1 which describes the power of one of the following emotions:

- Engagement/Boredom
- Frustration
- Meditation
- Excitement short term
- Excitement long term

I have found these emotions to represent quite well my mood. One thing to note is that boredom is not the kind of boredom one feels when they have nothing to do, but it is rather the opposite of engagement, according to Emotiv. See figure for a screenshot of the suite.

The Emotiv User Manual [emo, 2014] (page 31) provides information on the activities and brainwave types that may trigger each emotion.

Cognitiv™Suite

This is probably the most exciting feature of the Emotiv EPOC. Here, you can train 13 actions: push, pull, left, right, lift, drop, 6 rotations (one in each direction for the x, y and z axis) and disappear. The disappear action is more abstract because while the first 12 are real life actions, an object cannot vanish into thin air through whatever methods. The user has to train each action for a period of 8 seconds. This should be done multiple times until an as high as possible skill level is obtained. The more you get used to training, the easier it will become. I have achieved close to 100% on all 4 actions: push, pull, left, right. At one point, I was able to achieve 100% on the push action in 5 trainings. The SDK can only detect up to 4 actions at any one time, so one has to choose wisely which actions would be best for their application. See figure 3.4 for a screenshot of the suite.

Mouse Emulator (Gyro)

This data actually comes from a gyroscope fitted in the headset. The original version aims to emulate the mouse movement by changing the head position. Once your head turns to left or right and remains in that position, the centre of the circle becomes your new head position. However, I had access to the Unity 3D plugins and I was able to modify this suite so that the centre of the circle was not recalculated if the head stayed to the left or to the right because I wanted to use the gyro as yet another way to control the car movement. See figure for a screenshot of the suite.

3.1.1 Caring for the headset

The 16 sensors need to be properly hydrated before starting to use the Emotiv EPOC. The hydration is done with contact lenses saline solution which has the purpose of enabling a better transmission of the brainwaves while also sanitising the sensors. First time using the headset may need 15-20 proper hydrations before good contact quality is achieved.

When the user does not expect to use the headset in the next 3-4 days, it is recommended to remove the felt parts from the sensors. Otherwise, the process of oxidation happens more quickly. See figure 3.3 for images of clean sensors and oxidised sensors. The green residue can be cleaned with a cotton swab dipped into a solution of 1/2 water 1/2 white vinegar. If cleaning the interior of the golden plates, take care not to remove the slightly white polymer paste. I have left the felt parts in the sensors when I went on holiday for about 3 weeks. When I returned, the headset was losing contact quality very quickly and after about 15 minutes, it had to be rehydrated. It looks like salt columns may also form in the felt parts. My problem though, was that the golden plates oxidised a lot and after cleaning them as described above I achieved full green sensor contact quality which is the best you can wish for. I firstly cleaned the outside of the golden plates but that did not help too much. Then, I moved to cleaning the inside as well and that did the job for me, although on the Emotiv forums this is not something they would recommend. I was amazed to see the great contact quality I could achieve and it did not have any negative effects on the sensors and they are still in perfect shape 3 months after the cleaning.

3.1.2 Headset issues

One of the main problems I encountered is that the wireless connection to the computer is not reliable and it can drop out of the blue. The EPOC+ is now on the market and it seems it might come with a solution for this.

Figure 3.3: From left to right: clean inside of golden plate; clean outside of golden plate; oxidised inside of golden plate; oxidised outside of golden plate.

3.1.3 EmoComposer

EmoComposer is a tool which sends simulations of EmoEngine events to an application. This made it easy to test my game without connecting the headset. This was particularly useful in more tricky situations which would have meant spending a long time trying to achieve an action by concentration only.

3.1.4 EmoKey

EmoKey allows mapping of keys to all the interpretations described in this chapter. In this way, one can use the headset to send smiley faces when smiling or laughing for example. One may also use it to paint. These are two of the things that I have tried. It is supposed to be more useful for playing games using the headset. This has been tried in [Reinhold Scherer, 2012] for the *World of Warcraft* game.

3.2 Training

Because training is a difficult part of getting started with the headset, this section is only trying to provide some pointers as to what might work.

First of all, while training the user should try to keep as still as possible and concentrate on the action being trained. For example, if one is trying to train the push action, the thing which works most of the times is to visualise how the training cube is being pushed to the back of the virtual room.

Other people find it easy to visualise a flow of energy in the direction of the trained action.

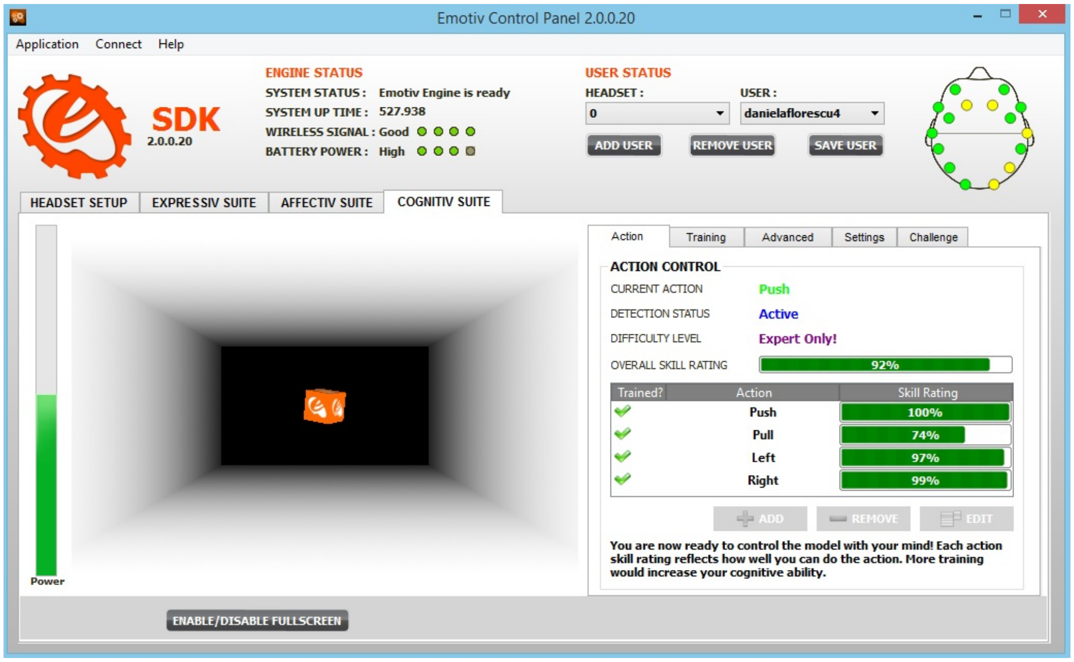


Figure 3.4: Cognitiv suite training profile

Repeating words into one's mind does not work. I have seen it working when people say words out loud but the same pace should be kept.

Doing hand gestures works sometimes as [Emotiv, 2015b] seems to suggest. I have seen one user trying to do this. It worked for a while but then it stopped. Same happened to me.

One thing I have not tried is shifting concentration on the left or right hand side of the body as it is also suggested in [Emotiv, 2015b].

Imagining colours or objects for different actions, also does not seem to work.

The problem with training is that there is no 'recipe' one can follow. Rather, the user has to try to come up with something that works for them.

With regards to the training success, in figure 3.4 you can see one of my achievements. [Emotiv, 2015b] the fastest learners seem to be young children who believe they can do anything, and very relaxed elderly. In the given example, the father of the poster, aged 82, was able to train reliably the 4 actions in less than 5 minutes. For some notes on how my user testing training worked, read chapter 7.

Some people might encounter difficulties in training the headset. According to [Carmen Vidaurre, 2009], between 15% and 30% of the people trying to use a BCI, will not be able to do so. This condition is called 'BCI illiteracy' and it better analysed by [Minkyu Ahn, 2013]. Their study suggests these people have high theta and low alpha waves present across different mental states such as non task related, resting before motor imagery and motor imagery. [Carmen Vidaurre, 2009] have tried to come with a solution to this by using a subject-optimised classifier.

3.3 Current Applications

In this section, I am going to have a quick go-through some of the existent applications developed with the help of the Emotiv EPOC.

- NeuroPhone [Andrew T. Campbell and Raizada, 2010] is an application which uses the P300 signal and allows the user to scroll through photos of 6 contacts at a time. Once the person the user is looking for is found, the application will dial that person's number.
- [Sam Fok, 2011] have developed a system which allows the control of a hand prosthetic which opens and closes a patient's hand.
- [Francesco Carrino, 2012] shows it is difficult to successfully control applications in a highly error sensitive context, such as a wheelchair.
- Mindtunes [Smirnoff, 2013] is a project in which DJ Fresh has used multiple headsets in order to produce music from the raw EEG data.
- EmoLens [Inc., 2010] tags a user's Flickr photos with emotions and learns to show similar pictures in the future as well as allowing picture search based on the tagged emotion.

Chapter 4

Design

4.1 Overview

4.2 Design Patterns

Chapter 5

Implementation

5.1 Interfacing with Emotiv

5.2 Scene description

5.3 Interesting aspects of development

Chapter 6

Results and analysis

Chapter 7

Testing and evaluation

7.1 User testing

Chapter 8

Conclusions

8.1 Achievements

8.2 Personal development

8.3 Further work

8.4 Summary

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Appendix A

Example of operation

An appendix is just like any other chapter, except that it comes after the appendix command in the master file.

One use of an appendix is to include an example of input to the system and the corresponding output.

One way to do this is to include, unformatted, an existing input file. You can do this using `\verbatiminput`. In this appendix we include a copy of the C file hello.c and its output file hello.out. If you use this facility you should make sure that the file which you input does not contain `TAB` characters, since LaTeX treats each `TAB` as a single space; you can use the Unix command `expand` (see manual page) to expand tabs into the appropriate number of spaces.

A.1 Example input and output

A.1.1 Input

(Actually, this isn't input, it's the source code, but it will do as an example)

A.1.2 Output

A.1.3 Another way to include code

You can also use the capabilities of the `listings` package to include sections of code, it does some keyword highlighting.