Export and Analysis of Emotiv Insight EEG Data via EEGLAB

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Export and Analysis of Emotiv Insight EEG Data via EEGLAB

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Since the release of Emotiv's new Insight EEG headset in 2015, this next generation wearable BCI headset's range in research, self assessment and cognitive performance increased drastically. This product started off with a Kickstarter pledge of $1,643,117 supported by 4,459 backers and ever since, the realization of the Insight EEG headset became a powerful solution to researchers, athletes, fitness trainers and anyone striving for personal health and well-being.

1. Introduction

The *Emotiv Insight* is a sleek, multi-channel, wireless headset that monitors your brain activity and translates EEG into meaningful data you can understand. At some point, if your aim is to use this headset for research purposes, like me, you would want to be able to analyze the raw EEG data with ease. Furthermore, if time and financial constraints are possible limitations in the course of your project, the need for a quicker and much easier way to accomplish this task exists. This document will explain how to record your EEG data in real-time, export it to EEGLAB and analyze the data accordingly. It stems from a research project that was done as part of the Biomedical Engineering Research Group (BERG) in the Department of Mechanical and Mechatronic Engineering at the University of Stellenbosch, South Africa.

1.1 Required Facilities

Apart from the laboratory space, the following tools were available to me and were used for the export and analysis of the data:

Computer: In order to export, evaluate and analyze the data, an office computer or personal laptop with a serial port should be available.

MATLAB®: This Mathematical Software will be used in order to stream and process the EEG raw data. General data-analysis will be executed using built-in functions, like EEGLAB.

EEGLAB: Interactive Matlab toolbox for processing continuous and event-related EEG data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. Since it is an open-source platform, the EEGLAB toolbox can be downloaded here.

Emotiv® software: The software pertaining to the EEG headset used in order to generate algorithms used for the feedback training. Extensions of this software, the *Emotiv Xavier Testbench* and *Emokey*, can also be used to capture real-time raw EEG data and send serial data.

2. Preparation

Before you export EEG data, you should ensure that you are prepared and that you are aware of the steps involved to **capture** the EEG data in the first place. The following may act as a checklist for you to read through in order to prepare for your recording session:

1. **Emotiv EEG headset**
2. **Windows 7 compatible Laptop / Computer**
3. **Emotiv Xavier Controlpanel 3.1.19 (build 200):** The *Emotiv Control Panel* is a software that allows the user to monitor the status and features of the Emotiv Insight. After cognitive detections during training are mapped to keystrokes using Emokey, users calibrate their focus and training with each of four different driving commands.
4. **Emotiv Xavier Testbench 3.1.19:** Data collection will take place in real time, while the subject wears the *Emotiv Insight*. *Emotiv Testbench* receives EEG data packets in JSON format from the *Insight*'s USB dongle. The *Emotiv Testbench* runs as a background process on your computer and is responsible for directing headset data from the serial port to an open network socket. Any language or framework that contains a socket library should be able to communicate with it. Any EEG recorded data will then be exported to Excel compatible csv. format.

2.1 Device Setup

Battery Check

Before starting the recording of EEG data, the *Emotiv Insight* headset must be switched on and it should be verified that the built-in battery is charged and is providing power. If the headset battery needed charging, the power switch must be set to the **off** position and plugged into the laptop / computer, using the mini-USB cable provided with the headset.

Setting up the Device

The device can now be set up for each the user. The following steps should be followed before recording an EEG session:

Step 1: Hydrate the Sensors. Assemble the headset (refer to Figures 1 and 2). Fully saturate the felt pads using saline solution. When the headset is placed on your scalp, the pads should feel wet.

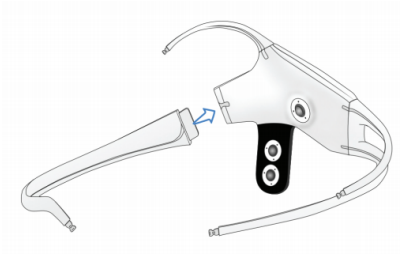


Figure 1: ***Step 1a***

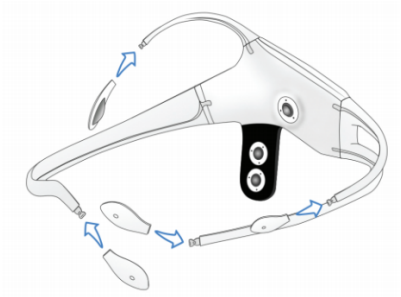


Figure 2: ***Step 1b***

Step 2: Put on Headset. Place the headset on your / the user's head (see Figure 3) and make sure good contact is made by the EEG electrodes on the scalp of the operator.

Step 3: Position Electrodes. Position the reference sensors to touch the skin behind the ear. It is critical that the reference sensors make contact with the skin behind the ear.

Step 4: Insert Dongle. Plug the dongle into your device's USB port. When a headset is paired, the indicator light should flicker rapidly (Figure 4). If it is blinking slowly or is not illuminated, reinsert the dongle and try again.

Step 5: Launch Software. On your Laptop / Computer, launch *Emotiv Xavier Test Bench* and *Emotiv Xavier Controlpanel*.

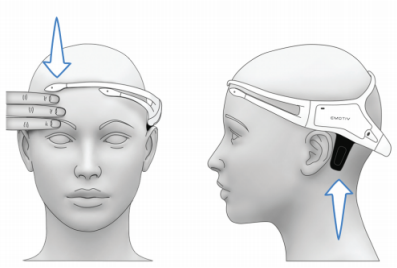


Figure 3: ***Steps 2 and 3***

Paired
The second LED will be lit,and the LED above
the power symbol becomes fainter and
flickers rapidly.

Figure 4: ***Step 4***

Step 6: Turn on Headset. The power switch is at the rear of the headset. A light indicates when the headset is on.

Step 7: Verify Signal Quality. Verify that the Wireless Signal reception is reported as Good by looking at the Engine Status box in the *Emotiv Xavier Controlpanel*. If it is not, make sure that the *Emotiv Insight SDK* Dongle is inserted into a USB port on your computer and that the single LED on the top half of the dongle is on continuously or flickering very rapidly.

2.2 Recording EEG data

Each session should be executed in parallel with the *Emotiv Xavier Testbench* software. Before initiating a training phase, a new recording session in the *Emotiv Xavier Testbench* programme was started:

1. Open **Emotiv Xavier Testbench**
2. Click on **Save Data**(Figure 5)
3. Enter the **configuration** for the output file (Figure 6)
4. Click on **Start**

At the same time, the session can be recorded with a voice recording application on your mobile phone (in order to keep track of the session duration).

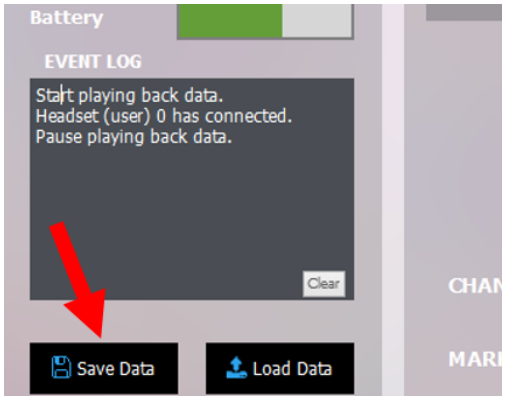


Figure 5: ***Save Data***

Algorithm Training

Since EEG data is being recorded, you can now use your research to test any type of motor / sensory function or just train your brain with a few learning algorithms, for example Lift, Drop, Left and Right. The following steps can be followed to accomplish this:

1. Open **Emotiv Xavier Controlpanel**
2. In the Controlpanel, in the top left, go to Options, Detections, **Mental Commands** (See Figure 7)

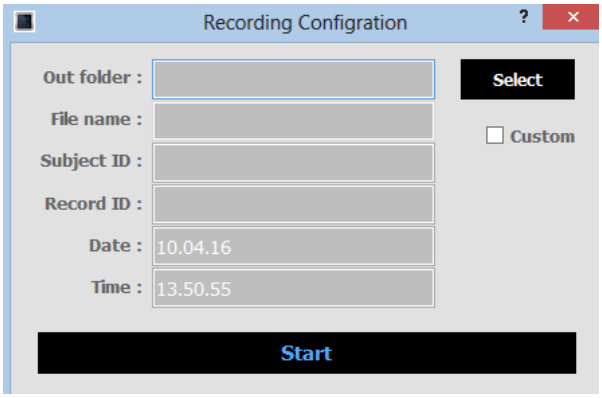


Figure 6: ***Enter Configuration***

3. Above the Action tab, go to Add User, Create **New Profile** and enter your details
4. Switch to the **Training** Tab
5. **Train Neutral** - The user will need to train the software to recognize their Neutral state - that is the user should sit still, and look away from the screen, clear their mind and try not to think about anything in particular
6. When Neutral training is complete, go to Options, **Callibration**
7. Train **Eyes open** and **Eyes Closed**. This is to distinguish between the Beta and Alpha brainwaves.
8. Under Live Metrics, press **Start Recording**
9. Go back to Options, Detections, **Mental Commands**
10. Under Action, add **Left** and **Right** directions
11. **Train** these directions. Once trained, the software will attempt to detect the difference which occurs in the user's brainwaves between the neutral state and the patterns which occur when the user thinks about moving the box.
12. If the patient struggles to concentrate, change **sensitivity** if necessary (Under the "Advanced" tab)
13. Do the same for **Lift** and **Drop**

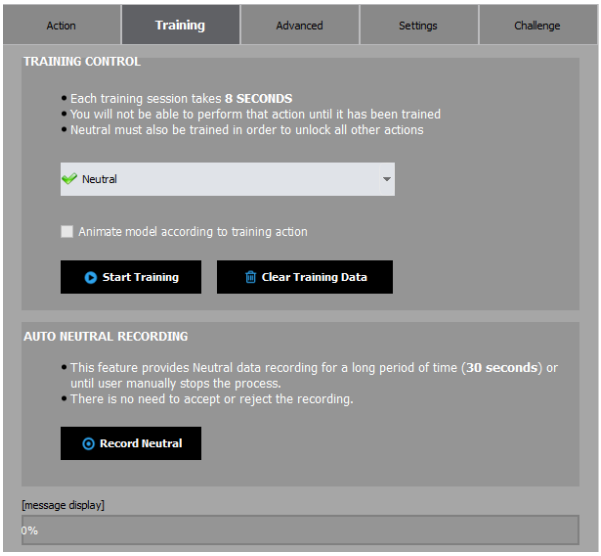


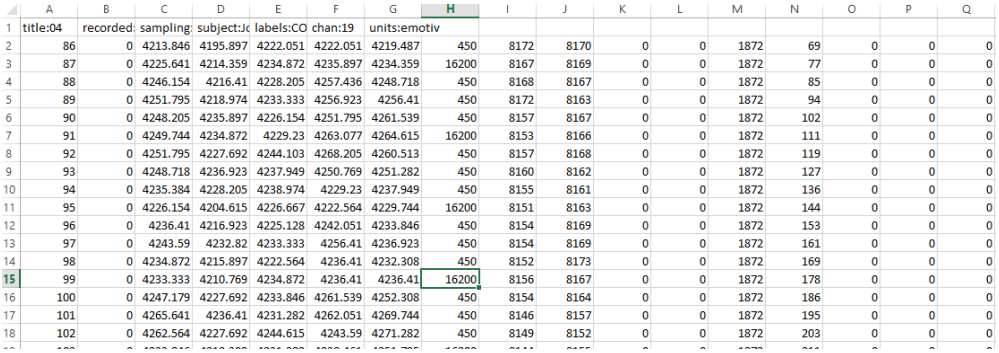
Figure 7: ***The Mental Commands window***

3. Exporting EEG data

Now that you have successfully recorded your EEG data, you can use Matlab to import the results. But first, it is necessary to convert the data to a readable format in order to make sure you know which data sets to import in EEGLAB. *Emotiv Insight Testbench* uses a standard file format called European Data Format (EDF), a format designed for exchange and storage of medical time series. Because of the fact that not all PC users have acess to software, such as Labview, to immediately view the raw data, you can convert the EDF data to CSV format (which can be easily read by Microsoft Excel). To do this:

1. Open **Emotiv Xavier Testbench**
2. Click on the Recording Configuration (Figure 5) and **Stop** the recording.
3. Under Options, **Tools**, Launcher EDF to CSV Converter, be sure to save the CSV file in the same directory as well.

You can now open the newly converted CSV file with Microsoft Excel. This will look more or less like Figure 8. Note that the EEG data can be seen in columns C:G, as they are the columns with the higher amplitudes of data - this will be referred to later.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	title:04	recorded:	sampling:	subject:J	labels:CO	chan:19	units:emotiv										
2	86	0	4213.846	4195.897	4222.051	4222.051	4219.487	450	8172	8170	0	0	1872	69	0	0	0
3	87	0	4225.641	4214.359	4234.872	4235.897	4234.359	16200	8167	8169	0	0	1872	77	0	0	0
4	88	0	4246.154	4216.41	4228.205	4257.436	4248.718	450	8168	8167	0	0	1872	85	0	0	0
5	89	0	4251.795	4218.974	4233.333	4256.923	4256.41	450	8172	8163	0	0	1872	94	0	0	0
6	90	0	4248.205	4235.897	4226.154	4251.795	4261.539	450	8157	8167	0	0	1872	102	0	0	0
7	91	0	4249.744	4234.872	4229.23	4263.077	4264.615	16200	8153	8166	0	0	1872	111	0	0	0
8	92	0	4251.795	4227.692	4244.103	4268.205	4260.513	450	8157	8168	0	0	1872	119	0	0	0
9	93	0	4248.718	4236.923	4237.949	4250.769	4251.282	450	8160	8162	0	0	1872	127	0	0	0
10	94	0	4235.384	4228.205	4238.974	4229.23	4237.949	450	8155	8161	0	0	1872	136	0	0	0
11	95	0	4226.154	4204.615	4226.667	4222.564	4229.744	16200	8151	8163	0	0	1872	144	0	0	0
12	96	0	4236.41	4216.923	4225.128	4242.051	4233.846	450	8154	8169	0	0	1872	153	0	0	0
13	97	0	4243.59	4232.82	4233.333	4256.41	4236.923	450	8154	8169	0	0	1872	161	0	0	0
14	98	0	4234.872	4215.897	4222.564	4236.41	4232.308	450	8152	8173	0	0	1872	169	0	0	0
15	99	0	4233.333	4210.769	4234.872	4236.41	4236.41	16200	8156	8167	0	0	1872	178	0	0	0
16	100	0	4247.179	4227.692	4233.846	4261.539	4252.308	450	8154	8164	0	0	1872	186	0	0	0
17	101	0	4265.641	4236.41	4231.282	4262.051	4269.744	450	8146	8157	0	0	1872	195	0	0	0
18	102	0	4262.564	4227.692	4244.615	4243.59	4271.282	450	8149	8152	0	0	1872	203	0	0	0

Figure 8: ***The contents of the CSV document***

Next open Matlab. In this example, I have a student-license Matlab 7.10.0 (R2010a). The following steps were obtained from the Swartz Center for Computational Neuroscience webpage: To install EEGLAB

1. Unzip the EEGLAB zip file in the folder of your choice
2. Start Matlab
3. Change the Matlab path to the EEGLAB folder you have just uncompressed
4. Type **eeglab** and press enter on the Matlab prompt

This will open the default EEGLAB dataset window shown in Figure 9. You now need to import your data.

Step 1: Import data. Go to File, Import data, Using EEGLAB functions and plugins, From EDF/EDF+/GDF files (Biosig Toolbox). You can then browse your files to find the EDF file obtained during your recorded session earlier.

Step 2: Load Biosig data. The figure shown in Figure 10 will open. You now need to specify the channel list. This is perhaps the most important step, as this means that you are actually importing the individual columns of the CSV data. Here I have entered **3:7**, which means it only imports columns 3-7 (i.e. Columns C-G). Also make sure that the boxes for 'Extract event' and 'Import anotations (EDF + only)' are checked. Click **OK**. This will open the next dialog box, allowing you to name and save it. Verify that the Channels per frame are 5, which is the number of columns you imported.

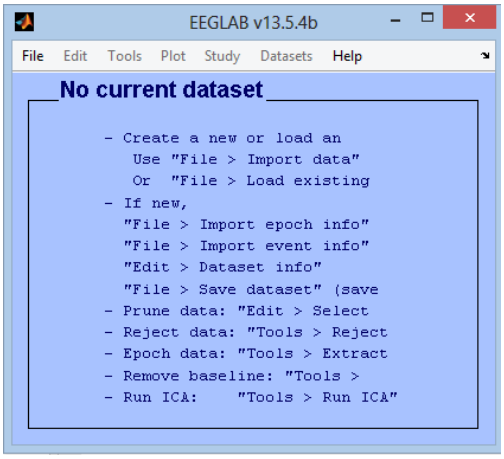


Figure 9: ***The EEGLAB dataset window***

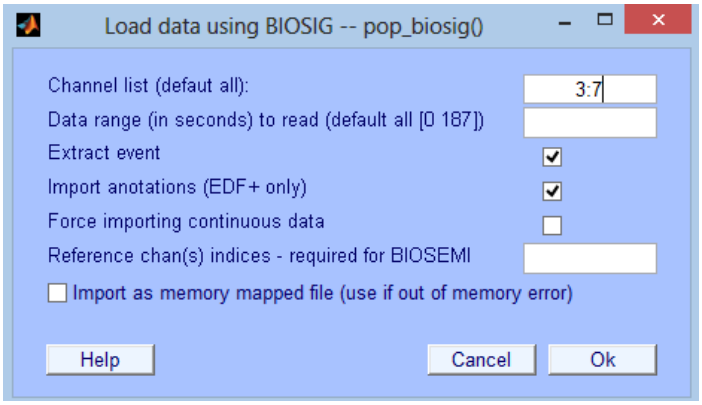


Figure 10: ***Specifying Channel Columns***

Step 3: Load Channel Location data. The channel locations are part of the 10-20 system (an internationally recognized method to describe the location of scalp electrodes in the context of an EEG experiment), and are in the following positions: AF3, AF4, T7, T8 and Pz (see Figure 11). Unfortunately *Emotiv* has not yet released a channel location file for the *Emotiv Insight* (that I know of), so I have altered the EPOC .ced file to only include the 5 channels mentioned. Go to Edit, Channel Locations, Cancel, Read locations and select the file: insightCED.ced. It can be downloaded here. When the file format window opens, just click **OK** (on autodetect). This will load the channel locations. You can alter a few settings if you want, but you can just click on **OK** again.

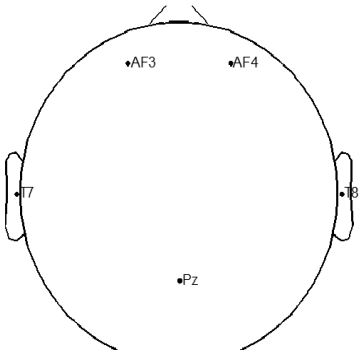


Figure 11: ***Insight Channel Locations***

You can also plot the channel locations by going to Plot, Channel locations, by Name or by Number.

Step 4: Run the ICA. Decomposing data by ICA (or any linear decomposition method, including PCA and its derivatives) involves a linear change of basis from data collected at single scalp channels to a spatially transformed virtual channel basis. That is, instead of a collection of simultaneously recorded single-channel data records, the data are transformed to a collection of simultaneously recorded outputs of spatial filters applied to the whole multi-channel data. To compute ICA components of a dataset of EEG epochs (or of a continuous EEGLAB dataset), select Tools, Run ICA. This calls the function *pop runica.m*. To test this function, simply press **OK** (SCCN, 2009).

The Matlab Command window will now iterate through a number of steps. This usually takes a few minutes, depending on the duration of your recording session. When this has finished, go to Tools, **Remove Baseline** and **OK**. You are now ready to use your data (which can be viewed by accessing Plot, **Channel data (scroll)**).

References

[Swartz Center for Computational Neuroscience, 2009] Center of the Institute for Neural Computation [online]. What is EEGLAB?. *Available at:* http://sccn.ucsd.edu/eeglab/downloadtoolbox.php.