Analysis of Performance Metrics Using *Emotiv EPOC+*

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Abstract. Brain-computer interface (BCI) is a device that enables the connection between the human brain and a computer, therefore, it allows us to observe the brain activity. The goal of this article is to prove that brain-computer interface is a helpful and quite precise tool. This goal will be achieved by presenting various examples from real-life situations. The results show that this device is indeed helpful, e.g. in a medical field, however, it is not commonly used in hospitals.

1 Introduction

The EEG curve (Electroencephalogram) is a record of the time change of electric potential caused by brain activity (also known as EEG signal). This biological signal is different for everyone (depending on age, gender, vigilance and other factors). However, its character and features are always the same which is the reason why the signal is worth recording and processing. More information about the EEG curve can be found here [3].

The signal can be captured by an invasive, partially invasive or non-invasive method. With the invasive method, the electrodes are implemented right to the grey cerebral cortex during neurosurgery procedures. By doing it this way, the signals are the highest quality of all the other methods. However, a disadvantage is a permanent brain damage. When doing the partially invasive method, the electrodes are implemented inside of the skull, but also outside of the brain. The quality of the signal is much better than during the non-invasive method and the risk of damaging the cerebral tissue is lower. During the non-invasive method, the electrical signal is captured from the surface of the head. These individual methods are described here [2].

The BCI *Emotiv EPOC+* device (further referred to as helmet) captures signals using the non-invasive method, specifically by measuring voltage potentials from the skull surface.

In our case, the EEG signal is measured and processed directly by an app called *Xavier*. This app was made by the same creators of the helmet. The free standard version of *Xavier* allows us not only to capture the metrics of performance (interest / affinity, excitement, frustration, engagement, relaxation, focus, long term excitement) and face expression, but also to control the subject of the human mind. The paid version of *Xavier* offers an analysis of raw, unprocessed EEG signals. This could help with developing a new software.

This article deals with measuring the metrics of performance during some specific activities using the free version of the app *Xavier*. It also shows a possible use of capturing these metrics in real life situations and other professional fields [1-2].

The first part of the article mentions processing the signal, but only theoretically as it is already integrated in the *Xavier* app. Then there is the BCI chapter which explains the concept of Brain Computer Interface – its example is the *Emotiv EPOC+* which we used. The *Emotiv EPOC+* is then described (including its characteristics). After that, we move on to the Experimental part with all the results. The last part of this article is the Conclusion chapter that briefly goes through all the results and possible solutions.

2 Signal Processing

The EEG signal that is captured by the non-invasive method from the surface of the head, is formed by the activity of neurons and its level of voltage is low (5-300 uV) and that's why it's necessary to process it. The processing is integrated in the *Xavier* app. It happens in several steps:

1. The preparation: Amplification of the signal and removal of artefacts.
2. Digitalization: Continuous electrical biosignal is converted into a discrete sequence of signal samples of certain time intervals.
3. Processing the digital signal: This signal is then processed using the *Xavier* app.

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3 Brain Computer Interface

The BCI device enables the connection between the human brain and a computer. This device captures and analyses biological EEG signals to use them for controlling external devices and measuring performance metrics, but also to make rehabilitations much easier etc.

We can see the main principle of how the BCI device works in the picture (Fig. 1). At first, the brain activity is measured using electrodes. Then, the measured signal needs to get amplified. Although the BCI device is not very known yet, it does have a future of helping people who deal with poor health conditions. There are some other devices based on a similar system, however, none of them are as simple to use as the BCI. The other devices usually require physical movement, whereas the BCI devices works with neural activity only, making it much easier for the users [2, 5].

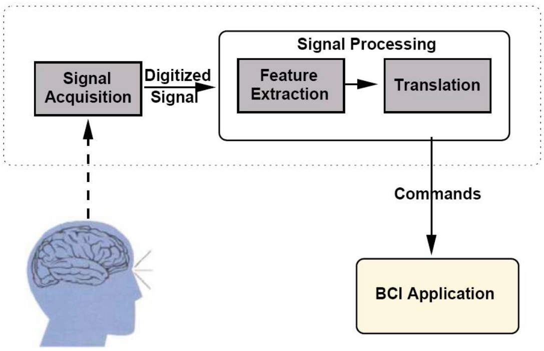

Fig. 1. Diagram of BCI system.

4 *Emotiv EPOC+*

Emotiv EPOC+ (Fig. 2) is a non-invasive BCI device meant for scalable and contextual human brain research and it provides access to professional grade brain data with a quick and easy to use design.

Emotiv BCI device works using the International 10/20 system. This $799 device (the Research Development Kit) comes as a set with a helmet that lets us observe the brain activity including emotions and intentions of the examined person. The set also includes 16 scalp sensors that work rather well, but it can be a little difficult to connect them properly sometimes. These difficulties are described in a next subchapter The connection [4].

Fig. 2. *Emotiv EPOC+.*

The helmet can detect:

- Facial expressions: blink, wink (left/right), look (left/right), furrow (frown), raise brow (surprise), smile, clench teeth (grimace), laugh, smirk left/right.
- Performance metrics: interest / affinity, excitement, frustration, engagement, relaxation, focus, stress, long term excitement.
- Mental Commands: push, pull, lift, drop, left, right, rotate clockwise, rotate anti-clockwise, rotate forwards, rotate backwards, rotate left, rotate right, disappear.

In this paper, Emotional states are also described and researched in experimental part.

4.1 The Connection

As mentioned previously, the scanning is based on the non-invasive method. Before the helmet can be put on the head of the person who is being examined, there is some preparation that needs to be done.

Firstly, it's necessary to lubricate the sensors that are kept in a special case. After the lubrication, the sensors can be connected to the helmet which is then put on the head. Next, the helmet gets turned on and connected to a computer. All the sensors don't usually get connected at once (as we can see in Fig. 3) and they need to be fixed manually until the connection gets better.

In the picture (Fig. 4) we can see a red colour. It indicates that a certain sensor isn't touching the skin well enough. Green, on the other hand, indicates that it is perfectly in place and the measuring can begin.

Note: It's been proven that for clearer results, it is better to examine people with short hair rather than long hair. This is due to the fact that long hair isolates the contact and thus, the connection gets worse.

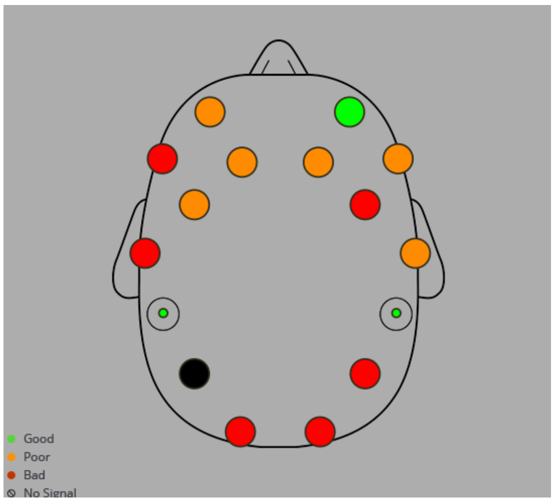

Fig. 3. Electrodes contact quality – bad.

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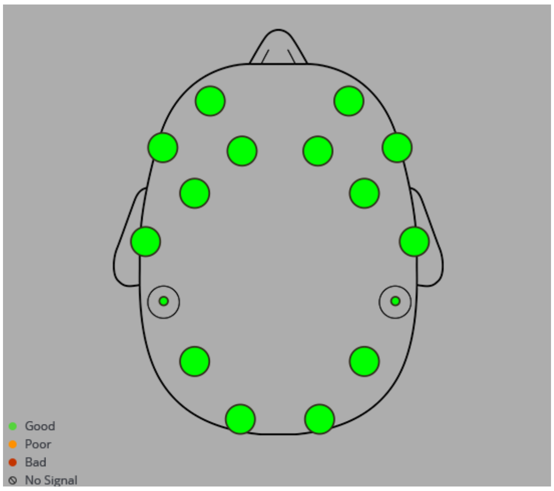

Fig. 4. Electrodes contact quality – good.

5 Experimental Part

5.1 Example 1: Math Exam

The first example describes how the performance metrics were captured while the examined person was writing a math exam. This exam consisted of 2 exercises – one of them was more difficult, requiring a lot of thinking, while the second one was quite easy. This process can be seen in picture (Fig. 5). The pink colour shows interest, the dark green means engagement, the light green stands for stress, the blue is for relaxation, the red means long-term excitement and finally, the purple shows focus.

These factors tell us that the student was busy throughout the whole exam – this has to do with interest (the engagement and interest curves have a similar course). The focus and stress curves are a bit more interesting – when the student was doing the first (more difficult) exercise, it was more stressing for him than during the second exercise. Another important part is the look of the stress curve when he was told the exam was over.

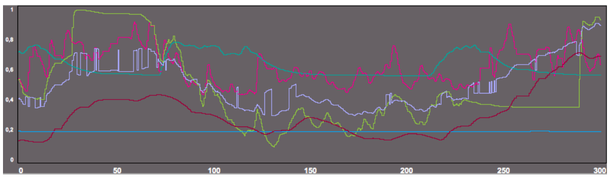
Fig. 5. Example 1 – Math exam.

5.2 Example 2: Rehabilitation

The second example is the use of the performance metrics in hospitals during rehabilitations. Because of the BCI device, the hospital worker is able to see if an exercise is stressful for a patient (or if it's not doing any physical difference to them and therefore it isn't helping the patient at all). Due to this, the worker can make a new rehabilitation plan for the patient. The picture (Fig. 6) shows a patient during his rehabilitation in the University Hospital in Ostrava.


Fig. 6. Example 2 – Rehabilitation.

5.3 Example 3: Football Match

The last example shows a man watching a football match. It was cut to show only a six-minute part of the whole record because this is the part where there was a high probability of scoring a goal. In this picture (Fig. 7) we can see the stress level rising to its double level. That was due to the possibility of scoring a goal that, in the end, the players didn't manage to score.

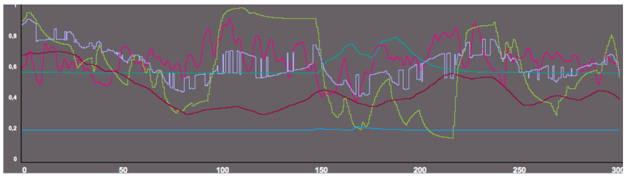
Fig. 7. Example 3 – Football match.

6 Conclusion

The BCI is not a new invention and as useful as it is, it isn't commonly used in hospitals. Judging by the experiments, we can see that the results of this method are quite accurate. Our university works with a hospital that enjoyed trying this method and all the doctors saw it as a useful thing. However, it does have a weakness – the preparation for measuring takes a lot of time (the sensor lubrication and connecting it to a software takes about 7 to 10 minutes). If the research ends up being even more useful and helpful in the future, our university plans to buy the full, paid version so that our research can be taken to the next level. The paid version of this app offers extracting the EEG signal and then process it using statistics or informatics methods or neuronal networks. This can help us build a useful software that helps doctors diagnose brain disease or abnormal behaviour of the brain.

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