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Real Time Brain Signals Viewer

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Abstract: This paper addresses the successful integration of Emotiv EPOC and Unity for real-time visualization of brain signals, representing a significant advance in understanding and interacting with brain activity. Real-time visualization of brain signals offers fundamental opportunities in neuroscience, brain-computer interface, and cognitive therapy. Through this study, a solid methodology was established to acquire, process, and graphically represent brain signals in 2D, allowing for an immersive and research-based experience. The results, products generated and implications in areas such as BCI and cognitive therapy are presented. Additionally, future exploration of integration with virtual reality and clinical validation is proposed to advance the understanding and application of real-time brain activity. This research lays the foundation for low-cost research and applications, promoting a deeper understanding of the human mind and its interaction with technology.

Keywords Brain signals · 2D visualization · Real time signals · emotiv-epoc · Unity

1 Introduction

Visualizing brain signals in real time is a fundamental tool in neuroscience and cognitive research [1]. It enables a deeper understanding of brain activity in various situations and contexts, opening possibilities for clinical, research and brain-computer interface (BCI) applications [2]. Brain wave analysis provides crucial information about an individual's mental, emotional, and cognitive state [3]. The real-time study and visualization of these brain waves has become more accessible thanks to technological advancement, including devices such as Emotiv EPOC [4], which captures non-invasive brain signals. This article focuses on the integration of Emotiv EPOC and Unity, a game-engine, for real-time visualization of brain waves and exploring its possible applications [5].

Below is a review of the literature that supports the importance and relevance of this research. Real-time visualization of brain signals is crucial for understanding brain function, both under normal and pathological conditions. It allows you to identify complex patterns and correlations that would otherwise be difficult to perceive [6]. The visual interpretation of brain activity can help understand cognitive [7], emotional, and decision-making processes. In clinical studies, real-time brain wave visualization is used for monitoring and diagnosing brain disorders such as epilepsy, attention, and hyperactivity disorders (ADHD) [8], and dementia. Additionally, in BCI environments [9], real-time visualization facilitates interaction between the brain and external devices, allowing control of wheelchairs, prostheses, and other devices [10]. The goal of this research is to address the need to build a replicable system that allows real-time visualization of brain waves using Emotiv EPOC and Unity. The aim is to develop a technical solution that provides an intuitive, real-time graphical representation of brain activity, paving the way for future research and interactive applications. The integration of devices like Emotiv EPOC and development environments like Unity represents a significant opportunity to advance this area and develop innovative applications.

2 Problem

Real-time brain wave visualization is an essential tool for understanding the functioning of the human brain [10]. Traditionally, obtaining and analyzing brain signals were complex and expensive processes, reserved

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primarily for laboratory environments. However, with the advent of devices such as Emotiv EPOC, which offer more affordable and non-invasive access to brain activity, it has become possible to explore new applications and approaches [11].

Despite advances in technology accessibility, there is still a lack of replicable systems that integrate electronic devices like Emotiv EPOC with development environments like Unity for real-time visualization of brain waves. The scientific community and developers face the challenge of building effective and standardized systems that allow this integration in an effective and easily reproducible way.

The lack of a standardized solution limits progress in research and practical applications. Creating a replicable system, as proposed in this research, is crucial to address this gap and facilitate future advances in neuroscience, BCI, psychology, and other related disciplines. This research is justified by the need to advance in the field of visualization of brain signals in real time and its practical application. The integration of Emotiv EPOC and Unity [12] offers significant potential to explore new frontiers in areas such as cognitive therapy, brain-computer interfaces, brain training and virtual reality.

A replicable solution that allows brain waves to be visualized in real time is an essential step towards more interactive and impactful applications. The development of this solution could lead to significant advances in the design of technologies that improve the quality of life of people with disabilities, allowing communication and interaction with the environment more effectively. Additionally, it could foster education and public understanding of the human brain and its processes.

3 Proposal

The proposed solution is presented in two block diagrams. The first diagram explains the development process from data acquisition to export and subsequent reading. While the second diagram shows the operation of the solution expressed in programming modules with a vision by functions (Fig. 1).

For the development, starting points have been taken from two different points: the origin of the data and the processing of the information received to visualize them numerically and as linear signals in 2D. From the data source we have the Emotiv Epoc device module, which starts with the connection and installation of the manufacturer's own drivers and launchers, to move on to the calibration part since a test user is required to obtain signals. It is necessary to place the sensors in contact

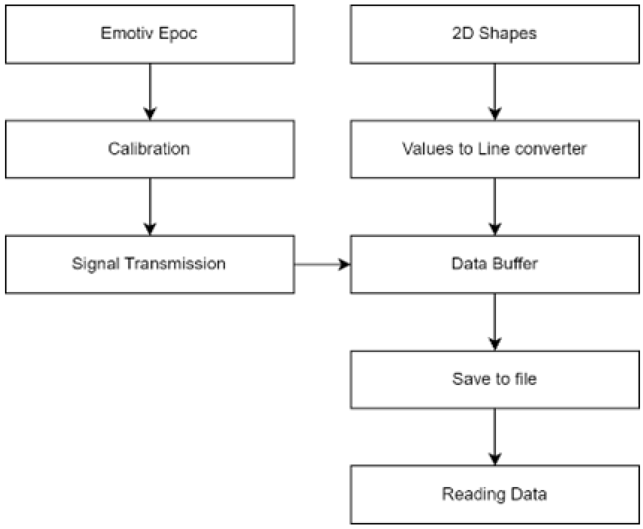

Fig. 1 Diagram of develop path.

with the scalp and add enough output solution to the sensors. In the Signal transmission block, the connection and data transmission are verified in real time from the manufacturer's own hub called Emotiv Launcher. On the other hand, from the game-engine environment, we start from the development of 2D Shapes that will represent the lines with the values of each signal that reaches the environment. This is achieved given that there is a coordinate system with amplitude on the Y axis and time units on the X axis. The location of the values in this Cartesian plane is the function of the block for transforming values into 2D lines. Next, the Data Buffer block is responsible for managing the data that arrives in real time, placing it in temporary memory, keeping it available for representation or storage.

Precisely the save to file block performs the task of storing the displayed data, not the received data, since in the user interface you can modify the time scale values or add marks, in this way the data that the user previously configured, the saving formats are in .CSV and .JSON which may be used by third parties or displayed again differently in a new version of the solution. The last block is developed to be able to view the files generated by the solution to re-view the information as a function of time once the data capture is completed, with the aim of sharing and viewing data between teams.

To visualize the solution in full operation, it has been captured in a diagram of modules that generally exemplify the process of visualizing brain signals in real time. In operation you can see 3 important sections, the main one is the module that runs in the Unity game-engine, the second is the real-time brain signal acquisition hardware Emotiv EPOC and the third module refers to the generated products for the solution: **i)** In the hardware section you can view the Emotiv EPOC device as it sends brain signals via Bluetooth to the PC, the block that receives, manages, and allows access to said signals is the manufacturer's own (Emotiv Launcher) [13], the Unity module is connected to this block. **ii)** This macro module is made up of two sections, 2d environment and the scripts section. The scripts section exemplifies all the programming carried out, which consists of a Subscription module, which connects to the Emotiv Launcher and manages the data it will obtain, the sending of authentication credentials (since it is a proprietary system, it is necessary to meet the requirements from the manufacturer to access the data) and allows you to read the sections of interest for the application. In this case, the subscribed sections are ECG (encephalogram data), Motion (data on the user's head movement), Facial Expressions (data processed by the launcher that directly allow us to know if the user smiles or grimaces), Mental Commands (they are pre-processed signals training the user to move objects (pull, push, left, right for example) [14]. These signals go directly to the records module which stores the displayed data in volatile memory and then writes the displayed data to files on the hard drive. It should be noted that a marker module has been added, which the user can place as a reference to a stimulus made to the user. tests as a timestamp that identifies this event. The data from the subscription module is also consumed by the serialization values module since it must be transformed into valid formats for later display. The next module through which the serialized data travel is the GameObject UI, which manages the user interface, that is, it allows you to decide the data that will be displayed, change parameters such as the scale in amplitude and function of time, the option has also been placed to numerically visualize the signal together with its 2D visual representation. **iii)** finally, there is the generated product management module which includes the export and import of files in .*CSV and Json format, for later viewing in the application or processing in third-party tools. A database module has also been added so that it can be made available in real time and consumed without the need for file transfers. See Fig. 2.

4 Test

This section describes the methodology used to test the real-time brainwave visualization solution using Emotiv EPOC and Unity. The initial conditions of the experiment, the procedures to follow and how the replicability of the results is guaranteed will be detailed. The testing objective of this solution is the visualization of user waves in real time without mental, logic or stress testing approach. Only the visualization of its waves will be carried out within the 2D environment and the manipulation of visualization parameters. To continue with the procedure, it is necessary to recalibrate the device with the new test user since everyone is a unique case.

1. Calibration is carried out using the tool provided by the manufacturer (see Fig. 3), Emotiv launcher.

2. It is necessary to place the sensors in the approximate position of the graph until reaching 100% connection (see Fig. 4). It may be necessary to increase the saline levels in each transducer to achieve the green color in all sensors.

3. Now it is necessary to ask the patient to calm down and breathe deeply with his eyes closed, all to achieve 100% signal capture in the ECG (see Fig. 5).

4. Next, run the solution in the Unity environment (see Fig. 6). It is recommended not to create an executable since in the testing stage it may be necessary to make hot adjustments for the correct visualization of the signals.

5. Select the information modules that you want to display in the 2D plane, in this case it will be the ECG and Motion (see Fig. 7).

6. ECG signals can be displayed in 2D line format in time domain, in addition to Motion data in numerical format (see Fig. 8).

7. Press the record button to start capturing the data displayed in the 2D environment.

Finally, the products resulting from the experiment can be viewed for subsequent review and analysis. In the case of replicability, it is detailed that each test is unique, and that the analysis of results focuses on obtaining the final products.

5 Results and Analysis

In this section, the results obtained from real-time brain wave visualization tests using Emotiv EPOC and Unity are presented. The products generated by the solution are described and their implications for future research and applications are analyzed. The successful implementation of the solution has generated the following products:

1. Signal Structure: A complete and structured collection of all brain signals recorded during testing. Includes preprocessed data and relevant metadata in JSON format (see Fig. 9).

2. Excel File for Processing: An Excel file that contains the brain signals ready to process and analyze, contains the values with their respective timestamp, as well as a column in which you can detail the markers made by the investigator (see Fig. 10).

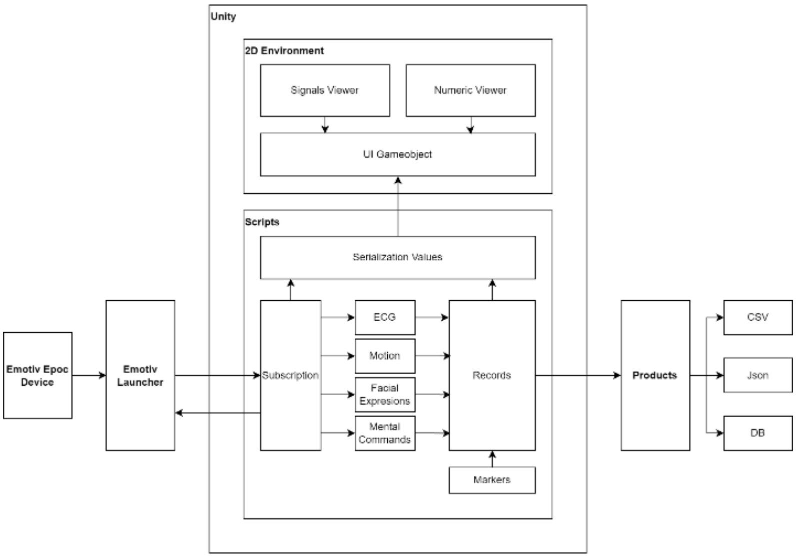

Fig. 2 Main function diagram.

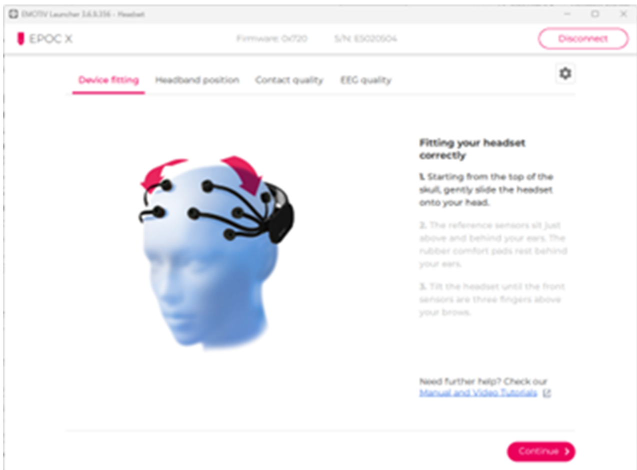

Fig. 3 Configure EMOTIV screen.

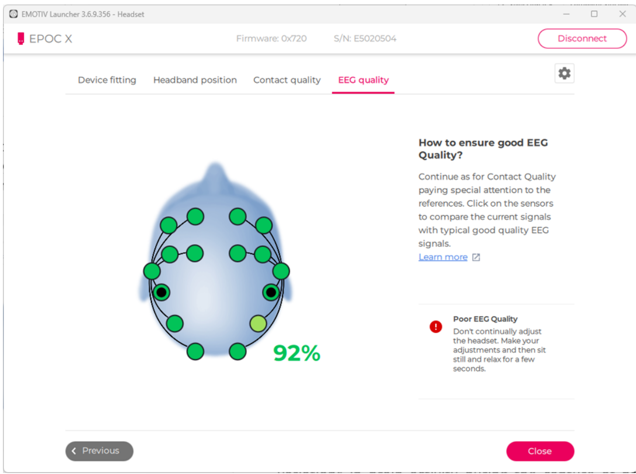

Fig. 5 Check of the ECG Quality status.

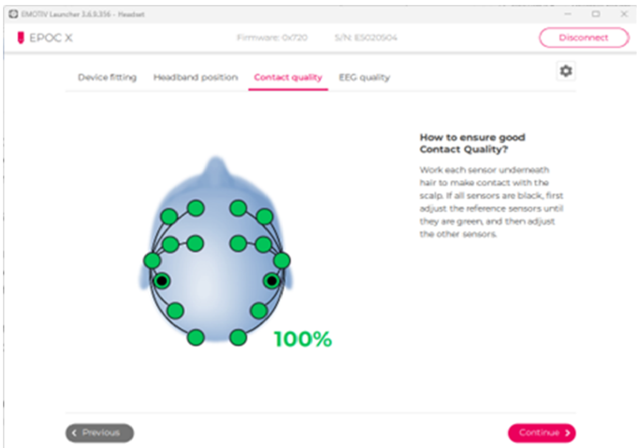

Fig. 4 Dashboard of the 16 sensor status.

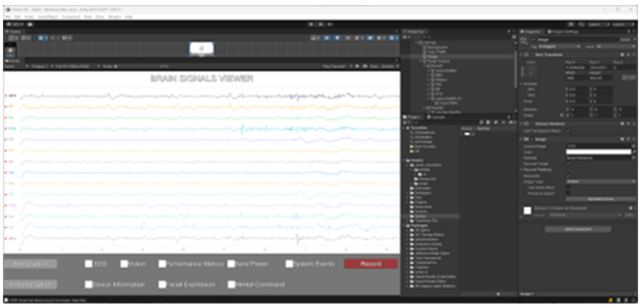

Fig. 6 Unity screen with the proposal.

In addition, you can view one in real time when a file generated by this application is opened. With a time-dependent slider that allows you to recreate the captured signals for greater ease of visualization by the researcher. This animation allows an intuitive under-

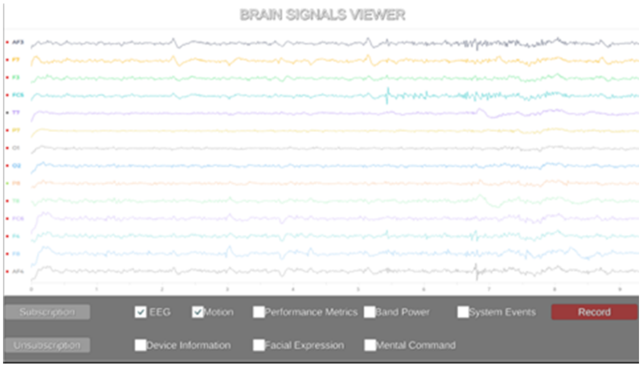

Fig. 7 UI for control the data from EMOTIV.

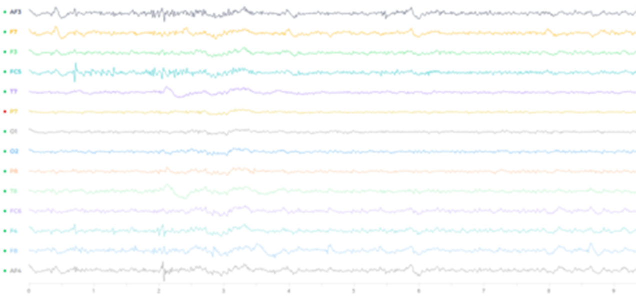

Fig. 8 Graph of signals from EEG in Real-Time.

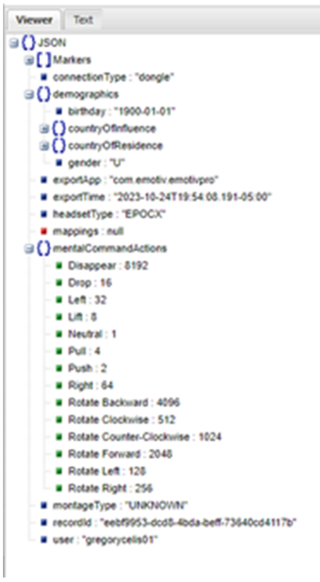

Fig. 9 Data structure in JSON.

standing of the variations in brain activity during the capture of brain signals.

6 Conclusions

Possible directions for future research and applications based on this solution are proposed. The integration of Emotiv EPOC and Unity was successfully achieved for real-time visualization of brain waves, providing a graphical and interactive representation of brain activity. The generated products, including signal database, ready-to-process Excel file and interactive animation, are useful resources for future research and applications. The solution has significant implications in fields such as brain-computer interface, cognitive therapy and neuroscience research, showing its potential to transform the way we interact with technology and understanding of the human brain.

Conflict of interest

The authors declare that they have no conflict of interest.

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	A	B	C	D	E	F	G	H	I	J	K
1	Timestamp	OriginalTimestamp	EEG.Counter	EEG.Interpolated	EEG.AF3	EEG.F7	EEG.F3	EEG.FC5	EEG.T7	EEG.P7	EEG.O1
2	1.698.012.478.052.480	1.698.012.478.052.960	108.000.000	0.000000	3.785.512.939	3.758.333.252	3.872.564.209	3.841.538.574	4.388.461.426	4.508.205.078	4.524.102.539
3	1.698.012.478.056.380	1.698.012.478.056.770	109.000.000	0.000000	3.787.435.791	3.757.820.557	3.870.897.461	3.843.846.191	4.387.307.617	4.507.948.730	4.525.000.000
4	1.698.012.478.060.290	1.698.012.478.060.670	110.000.000	0.000000	3.793.333.252	3.762.179.443	3.873.461.426	3.850.000.000	4.389.358.887	4.507.948.730	4.526.153.809
5	1.698.012.478.064.190	1.698.012.478.064.570	111.000.000	0.000000	3.801.281.982	3.769.487.061	3.879.743.652	3.857.820.557	4.393.846.191	4.508.077.148	4.526.922.852
6	1.698.012.478.068.100	1.698.012.478.068.580	112.000.000	0.000000	3.809.230.713	3.777.051.270	3.887.692.383	3.864.615.479	4.398.589.844	4.508.077.148	4.526.922.852
7	1.698.012.478.072.000	1.698.012.478.072.480	113.000.000	0.000000	3.815.000.000	3.782.692.383	3.895.000.000	3.868.718.018	4.401.538.574	4.507.948.730	4.526.153.809
8	1.698.012.478.075.910	1.698.012.478.076.390	114.000.000	0.000000	3.817.820.557	3.785.769.287	3.898.974.365	3.869.358.887	4.401.794.922	4.507.563.965	4.525.384.766
9	1.698.012.478.079.810	1.698.012.478.080.290	115.000.000	0.000000	3.817.307.617	3.786.666.748	3.897.692.383	3.867.307.617	4.400.000.000	4.506.794.922	4.524.743.652
10	1.698.012.478.083.710	1.698.012.478.084.200	116.000.000	0.000000	3.814.487.061	3.785.897.461	3.891.281.982	3.864.358.887	4.397.692.383	4.505.512.695	4.523.974.121
11	1.698.012.478.087.620	1.698.012.478.088.000	117.000.000	0.000000	3.811.153.809	3.783.589.844	3.883.589.844	3.862.948.730	4.395.897.461	4.503.974.121	4.522.948.730
12	1.698.012.478.091.520	1.698.012.478.091.900	118.000.000	0.000000	3.809.102.539	3.780.769.287	3.878.846.191	3.863.076.904	4.394.871.582	4.502.820.313	4.522.179.688
13	1.698.012.478.095.430	1.698.012.478.095.810	119.000.000	0.000000	3.809.743.652	3.778.461.426	3.878.974.365	3.862.692.383	4.394.615.234	4.502.436.035	4.522.179.688

Fig. 10 Signals Data in CSV format.

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