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EEG Signal Analysis for Measuring the Quality of Virtual Reality

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Abstract: Virtual Reality (VR) is becoming popular and has been used in many kind of different purposes including entertainment, daily life activities and medical field. However, with the current VR technology, people are still be able to discriminate the VR from the real world very easily. Perhaps, the better way to develop the VR technology is not by considering how much VR looks like the real world but how much similar humans perceive from VR comparing to the real world. With this aspect, we perform experiments to show that the similarity in brain signal activity can be used as the measurement of the VR quality. We record EEG signals in occipital area of the brain and calculate the similarity between two signals obtained while the subject is observing VR objects and real world object. The results show that the similarity of EEG signal increases as the VR object becomes more similar to the real world object. This result suggests that the similarity of brain signal can be used as the measurement for VR quality.

Keywords: Virtual Reality, EEG, Signal Similarity

1. INTRODUCTION

Virtual Reality (VR) is the immersive multimedia or computer-simulated life that replicates an environment that simulates physical presence in places in the real world or imagined worlds [1]. There are many technologies and devices that provide VR experience to the user including Head Mount Display (HMD) devices such as Oculus Rift. However, there is a still big gap between the virtual reality and the real world environment with the current VR technology. Users can still easily discriminate between those objects in VR and real world. This doesn't apply for only visual sensation of human but also other sensations such as auditory and tactile sensation as well. The ultimate goal for the VR is to create environment with one that can mimic the real world environment as precise as possible and it is not about how much the VR has properties and quality to be similar to that of real world environment. Perhaps, it is about how similarity human "perceives" from the created VR comparing to the real world. With this aspect, measuring the similarity between the brain activity when subjects experiences the VR and real world environment is possibly the better approach to indicate the quality of the VR, and the VR device itself and thus, it can be used to improve the VR technology.

In this paper, we conducted the experiments to show that the similarity of brain signals can be used as the measurement for the VR quality. The motivation for this paper comes from the work of D. Perani in [2] where they perform the experiment to find the brain activity of the subject while watching the real world hand grasping action in compared to the 3D model in different degree of similarity to the real human hand action using PET scan to represent the brain activity. Electroencephalogram (EEG) is the choice for this experiment because EEG signal measurement can be performed noninvasively and easily with cheap cost and also in real time.

2. METHOD AND EXPERIMENT

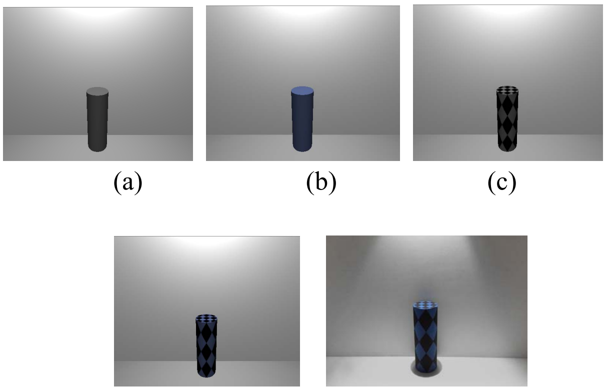
2.1 Subject and EEG data acquisition

Five healthy male subjects (age 25 ±2 years) voluntarily participated in our experiment. All of the subjects were of the same laterality (right-handed), free of any neurological disorders and eyes diseases, and had never experienced using Oculus Rift with 1280x800 resolution display. The lens of Oculus Rift is adjusted to be match with subject's eyesight.

EEG signal was acquired from Occipital lobe region of the brain using Open BCI 32-bit Board Kit with sampling rate equal to 250 Hz. The node locations are O1, O2, Oz, PO3, PO4, O9, O10 and POz according to the extension version of 10-20 International System.

2.2 Target object and virtual reality model

Fig. 1 shows the objects using as the target in the experiment. The real object using in this experiment was a blue cylinder with black-color-rectangle pattern on its surface (Fig.1 (e)). During the experiment the object is placed in the dark room with a single white light spot above the object. The virtual reality objects using in the experiment was then created by Unity software. The target 3D object is set in the environment mimicking the real world environment. In this experiment, 4 virtual reality objects: gray cylinder, blue cylinder, gray cylinder with pattern printed on the surface and blue cylinder with pattern printed on the surface, as shown in Fig.1 (a)-(d). (We use two terms textured gray cylinder and textured blue cylinder as to represent the last two objects, respectively). The virtual environments then are programed in Unity to be compatible to the Oculus Rift so that the subject can see the object in 3D.



(a) (b) (c)

(d) (e)

Fig. 1 Virtual reality objects: (a) Gray Cylinder, (b) Blue Cylinder, (c) Textured Gray Cylinder, (d) Textured Blue Cylinder, and (e) real object

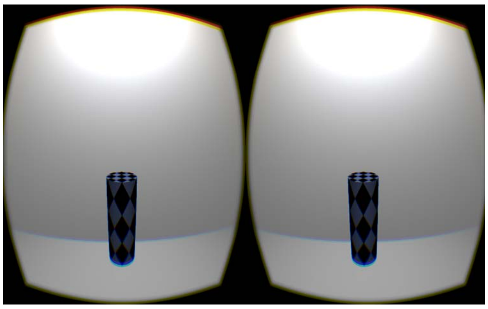


Fig. 2 Textured blue cylinder as being seen with the Oculus Rift

2.3 Experiment setup

The experiment starts as the subject sitting comfortably in front of the computer where all of the VR environments are installed. Open BCI device is prepared and EEG electrodes are attached to the subject's scalp. After the subject wears and adjusts the basic configurations for Oculus Rift, the EEG recording is then performed for each virtual reality object in the order of: gray cylinder, blue cylinder, textured gray cylinder and textured blue cylinder. The EEG signal is recorded 5 times per object with 10 seconds interval separated by 10 seconds of resting time. The subject was asked to focus on the center of the object and not to blink during the 10 seconds of EEG recording. The subject was asked to close their eyes before starting the experiment and the auditory cue is given to let the subject know when each interval starts and stops. After finishing the experiment with all four virtual reality object, Oculus Rift is removed from the subject and the subject is taken to the experiment setup for the reality object. The EEG signal is then recorded with the same procedure.

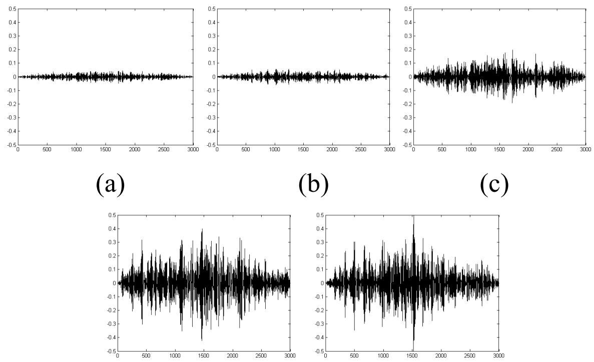
2.3 Signal Processing

The signal was first filtered into 5 frequency bands: Alpha (8-15 Hz), Beta (16-31 Hz), Theta (4 – 7 Hz), Delta (1-4 Hz) and Gamma (32-50 Hz). Then for each subject, the signal similarity between signals obtained from all pairs of VR object and real object is calculated. In this experiment, we use cross-correlation value to measure the EEG signal similarity. Cross-correlation is a measure of two signals for demonstrating degree of signal similarity as a function of the lag of one relative to the other [3]. The value of cross-correlation represents the degree of similarity between the two signals.

3. RESULTS AND DISCUSSION

3.1 Results

The cross-correlation values between the pair of signal from each VR object and Real object is shown in Fig. 3 below.



(a) (b) (c)

(d) (e)

Fig. 3 The Cross-correlation value for (a) Gray Cylinder, (b) Blue Cylinder, (c) Textured Gray Cylinder, (d) Textured Blue Cylinder, (e) Real-Real object

The signal similarities between each pair of trial have been calculated and average for all the subjects. Table 1 and 2 present the cross correlation values between signal obtained from each VR model and real object (column 2-5 in Table 1 and Table 2). Table 1 shows the cross correlation values by frequency bands averaged by all channels. In contrast, Table 2 shows the values by each channel with all frequency bands averaged. In addition, the cross correlation value is also calculated between the internal samples of signal obtaining from the real object itself (column 6 of Table 1 and Table 2).

Table 1. Average cross correlation values of 5 subjects for each frequency band

Frequency Band	Object type				
	Grey	Blue	T. Grey	T. Blue	Real
Alpha	0.2019	0.2160	0.2277	0.2494	0.5811
Beta	0.1787	0.1811	0.1833	0.2045	0.5840
Delta	0.4737	0.4744	0.5644	0.5944	0.9480
Gamma	0.1560	0.1533	0.1506	0.1566	0.5609
Theta	0.1151	0.1231	0.1392	0.1612	0.2921

Table 2 Average cross correlation values of 5 subjects for each channel

Channel /Node	Object type				
	Grey	Blue	T. Grey	T. Blue	Real
Ch1/O10	0.1812	0.1843	0.2049	0.2467	0.4829
Ch2/O2	0.2561	0.2354	0.2842	0.3223	0.6675
Ch3/PO4	0.2145	0.2393	0.2485	0.2877	0.5959
Ch4/Oz	0.2055	0.2182	0.2519	0.2684	0.6552
Ch5/POz	0.2865	0.2921	0.3222	0.3209	0.5657
Ch6/O1	0.1989	0.1977	0.2041	0.1990	0.5663
Ch7/PO3	0.2229	0.2411	0.2645	0.2808	0.6347
Ch8/O9	0.2353	0.2287	0.2444	0.2597	0.5776

The results for each pair of signals are then divided by the cross correlation value of the real object signal (column 6) to normalize the value for each sample. The normalized values are then plot in Fig.4 and Fig.5 below.

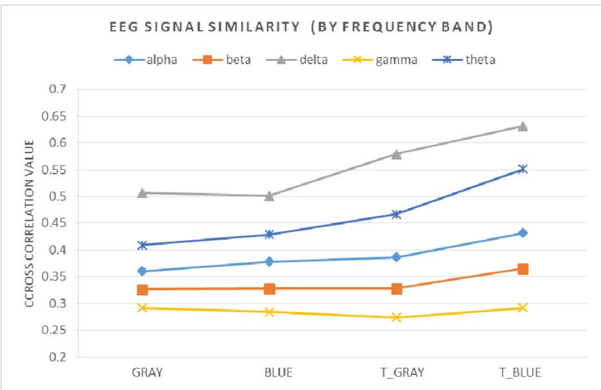


Fig. 4 The EEG signal similarity of each frequency band for all the virtual reality model.

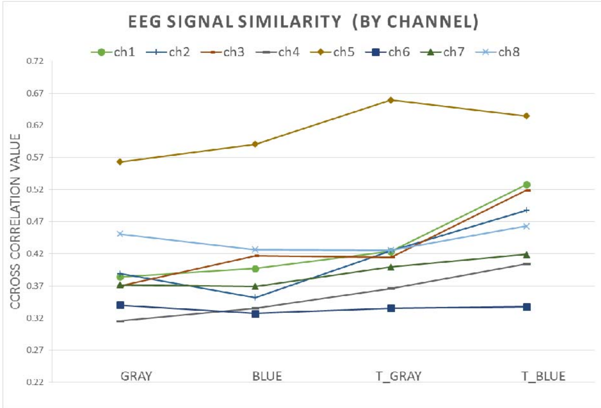


Fig. 5 The EEG signal similarity of each channel for all the virtual reality model.

3.2 Result discussion

We found that all the trend lines except gamma band case as shown in Fig. 4 have positive slope value. This indicates that the EEG signal similarity increases when the virtual reality model becomes more like the real object. For the frequency band case, theta band gives the highest value of slope equal to 0.0462 and delta band yields the highest average cross correlation value between each virtual reality model and the real object. For the channel case (Fig. 5), channel 1 (O10) has the highest slope trend line, and channel 5 (POz) gives the highest average value of cross correlation.

3.3 Future work and application

Even though the result shown in this paper supports the hypothesis that the EEG signal similarity increases when the virtual reality model becomes more similar to the object in real world, we could consider more different kinds of target object to be performed in the experiment, such as the variation of color, the size and shape of the object and the pattern texture on the object surface. The HMD devices can also be one of the variable in the experiment. Different kinds of HMD devices possibly yield the different result. In EEG signal acquisition, we could also use more nodes to consider the other part of brain than the Occipital lobe.

VR technology has been used in many different fields. Not only for the better experience in entertainment by VR technology, better quality for VR technology would become very useful for medical purpose such as rehabilitation using VR [4][5] or interfaces technology such as Brain Computer Interface (BCI) [6]. In these aspects, if the users can "perceive" the VR more similar to the real-world environment, it would definitely yield the better result and hence, one more step to the better technology for the mankind.

4. CONCLUSION

In this paper, we propose an alternative and possibly better way to measure the quality for VR devices and VR itself by measure the similarity of brain activity using cross correlation of EEG signal between the signal obtain when the subject observes different VR objects comparing to one obtained from observing the real world object. The result show that the similarity of brain activity is higher as the VR objects become more similar to the real world object. This suggests that EEG signal similarity can be used as the measurement for the quality of the VR technology. We assure that this work would make a contribution to the development of VR technology.

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