Virtual Game Scenario Generation Using Brain Computer Interface

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ABSTRACT

In this paper, we have proposed an effective method to control simulated foggy scene or racing car speed by using brain computer interface (BCI). Our method benefits much from the attention level value computed by the Thinkgear chip in Neurosky's MindWave headset. This EEG sensor, together with the atmospheric scatting model or the 2D game framework, is applied to control the fog density or the car speed of the virtual scenario. For the model-based foggy scenario simulation, virtual foggy scene is obtained by taking the predefined airlight and the transmission map into the atmospheric scattering model. For the software-based racing scenario simulation, the moving car is created by using the software framework Sprite and its speed is controlled by the EEG sensor data. Both methods are dominated by few parameters and can be used in computer games, mental strength recovery, concentration training and many other educational environments. The Experimental results show that the proposed model-based method and software-based method may generate quite visually pleasing game scenario with good sense of reality and immersion.

Keywords: Game scenario, brain computer interface, MindWave, attention level

1. INTRODUCTION

Brain-computer interfaces, which develop rapidly for several years, may be an interesting tool among other things for the implementation of control processes including virtual scenes. Since brain-computer interfaces (BCI) allow direct control of different applications using brain, the BCI technology is a clearly interdisciplinary issue combining sciences such as biomedical engineering, medicine, signal analysis, electronics and information technology [1]. Combined with the image rendering technology, the BCI interfaces can be used for mind control, medical diagnosis and therapy of the hyperkinetic syndrome of childhood, computer games, and attention quality training for children, etc.

This study aims to design a mind controlled virtual scene by using the BCI and image processing technology. The proposed method adopts Neurosky's Mindwave Mobile headphones as electroencephalograph (EEG) receiver, and the EEG data (attention level, meditation level, eye blink, etc.) can be transmitted to the computer through Bluetooth module. Here, we use human attention level as the key parameter for controlling various virtual scenes, which includes fog scene simulation and racing car game. Experimental results show that the proposed method can generate promising fog rendering effect or vivid personal gaming experience during the BCI control process. Since the proposed method provides fresh experience for the users, it can thus be widely used in medical, entertainment and education areas.

The paper is organized as follows. In Section 2, the related works about BCI technology and virtual scenario generation technique are reviewed. Section 3 describes the proposed model-based method and software-based method in details, and these methods are applied to fog scene rendering and racing game simulation. Experimental results of the proposed methods for two representative applications are presented in Section 4. In Section 5, we conclude the paper.

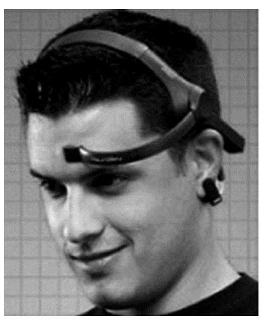
2. RELATED WORK

Since the proposed method combines the BCI with the image rendering and computer game technology. Therefore, this section first introduces the BCI technology that we used in our experiment, and then discusses the related research concerning virtual scenario generation.

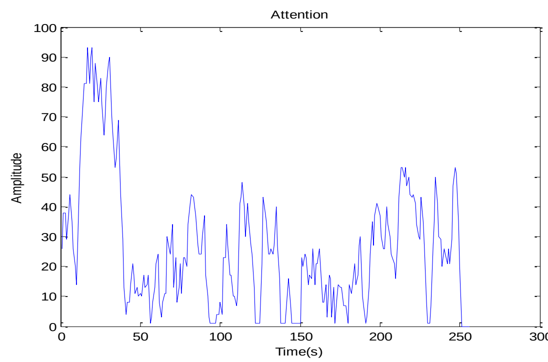
2.1 BCI Technology

There are two main types of BCI because of the reception of information from the human brain: interfaces based on the invasive method lie in the implementation of measurement electrodes directly into the brain of a patient, and interfaces based on the non-invasive method - they are often used due to the lack of interference in the human structure. Brain Computer Interfaces already developed are based on one of three paradigms: SCP - free cortical potentials characterized by a free communication; P300 - evoked potentials used to design synchronous BCI constructions; ERD/ERS - a desynchronization/synchronization associated with a stimulus. This phenomenon is to change the amplitude of the oscillations occurring in some bands when planning a move. There are a number of commercial grade EEG sensors available, including NeuroSky's MindWave, Emotiv's EPOC, Muse and Melon, etc. Nowadays, EEG sensors to determine the user's concentration or attention level while performing an activity have been used in the context of movies [2], archery [3], music [4] and gaming [5].

For the proposed BCI-based virtual game scene generation, we have chosen the Neurosky's MindWave headset, because it allows low-cost EEG-linked research by using dry sensors. MindWave safely measures brainwave signals and monitors the attention, meditation, different frequency signal intensities and raw signals. This hardware has all the necessary tools for programming and software development and is compatible with different platforms, which is essential to develop various user-friendly applications with emotional state monitoring. As can be seen in Fig. 1(a), this headset consists of an ear-clip and a sensor arm. One can clearly see that the arm sensor is resting on the forehead above the left eye. The reference and ground electrodes are on the ear clip. The sensor of MindWave headset is made of dry electrode which does not require any skin preparation or conductive pastes. The electrodes get the raw signal and Thinkgear chip then processes the raw signal and differentiate the value based on the frequency range. Besides, the headset is wireless which makes it convenient for controlling the virtual scenes. Fig. 1(b) shows an example of the recorded attention level value using MindWave headset.



(a) MindWave headset



(b) Recorded attention level value

Figure 1. The Neurosky's Mindwave headset with the recorded attention level value.

2.2 Virtual game scenario generation

There are several related works concerning the generation of virtual game scenario. These existing methods can be divided into two categories: model-based method and software-based method. The model-based method aims at establishing corresponding physical model to obtain the ideal rendering and animation effects. The software-based method generates rendering and animation effects using software tools. For example, the software tools, such as 3ds max, OpenGL, and Sprite for iOS platform, etc., can be used to generate virtual game scenario. In this paper, two representative examples of virtual game scenario generation are given to demonstrate the control processing of game scenario by using BCI technique. The first example is foggy scenario simulation which uses BCI to control the rendered environment in a model-based way, and the second example is racing scenario simulation which uses BCI to control a target car of the virtual racing game in a software-based way.

For the foggy scenario simulation, modeling the physical mechanism of fog makes it possible to simulate foggy conditions. Max et al. [6] introduced a single scattering model for light diffusion to generate haze in the atmosphere. Walter et al. [7] simulated the Mie Scattering and Nishita [8] used an improved sky illumination to render the fog scene. Sun et al. [9] proposed a practical analytic method to render the single scattering in fog, mist and haze in real-time. Wang et al. [10] proposed a sky light model considering atmospheric scattering and refraction. Based on the model, various sky scenes, including foggy day and other conditions, are realistically rendered. For the racing scenario simulation, human gesture and body motion are usually used for controlling the driving process of a car in racing game. Saha et al. [11] presented a robust gesture controlled driving system that provides the natural experience of driving while playing a simulator racing game. Guo et al. [12] used Microsoft Kinect as a whole body motion tracking system and 3D user interface to develop two different exercise-based interfaces in order to adapt a car racing game as an exergame. Although many work has been done in foggy scene simulation and racing game development, using EEG sensor to control the fog density or a racing car of virtual game scenario, as far as we know, is rare in literature.

3. PROPOSED METHOD

3.1 Method procedure

Fig. 2 shows the overall scheme of our virtual game scenario generation method. As can be seen in the figure, a stimulus (no-fog image or a racing car) is first given and demonstrated to a volunteer wearing Neurosky's MindWave headset. Then, the attention level was recorded one time per second, and the attention value we get from the EEG sensor is a value between 0-100. Next, the attention value is transformed into an adjustable parameter value of the proposed scenario generation method. Finally, a series of virtual foggy scenes can be generated by adding different fog veils on the input no-fog image for foggy scenario simulation, and the moving speed of a racing car can be controlled by designing an attention level-based speed dial. Therefore, we can deduce that the key steps for BCI-based virtual game scenario generation are the attention level value obtained by MindWave headset, and the virtual foggy scene or the virtual racing scenario created by the proposed method. The former foggy scene can be simulated by using a physical model, and the latter racing scenario can be achieved by adopting a reasonable software framework. Here, we adjust the fog density of the virtual scene by using the atmospheric scattering model, and adjust the speed of the racing car by using the Sprite framework. Both the foggy scenario and racing scenario are all controlled by the attention level value.

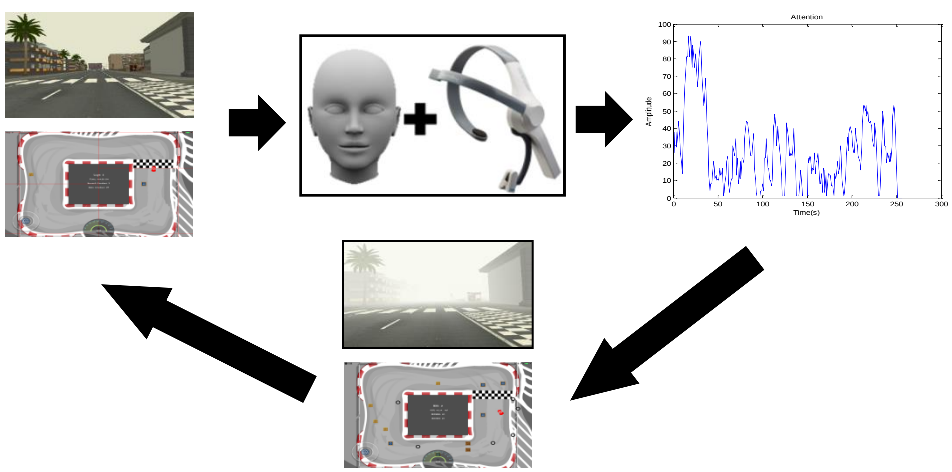


Figure 2. Overall scheme of our method

3.2 Virtual foggy scenario simulation

To simulate virtual foggy scene, the model that describes the formation of a foggy image is first analyzed here. For fog condition, light passing through a scattering medium is attenuated and distributed to other directions. This can happen anywhere along the path, and leads to a combination of radiances incident towards the camera, as shown in Fig. 3. The atmospheric scattering model that widely used to describe the formation of the foggy image is as follows [13]:

$$I(\mathbf{x}) = J(\mathbf{x})t(\mathbf{x}) + A(1 - t(\mathbf{x})) \tag{1}$$

where this equation is defined on the three RGB color channels. I is the observed image, A is the airlight color vector, J is the surface radiance vector at the interaction point of the scene and the real-world ray corresponding to the pixel $\mathbf{x} = (x, y)$. $t(\mathbf{x})$ is called transmission map and it expresses the relative portion of light that manages to survive the entire path between the observer and a surface point in the scene without being scattered. Theoretically, the goal of virtual foggy scene simulation is to calculate J from the no-fog image I, the transmission t and the airlight A.

Once we have the input no-fog image $I(\mathbf{x})$, the transmission map $t(\mathbf{x})$, and the airlight A is fix to [248, 249, 255] for all the results reported in this paper, the final simulated foggy image $J(\mathbf{x})$ can thus be obtained according to the atmospheric scattering model [see Eq. (1)]. This process can be written as:

$$J(\mathbf{x}) = \frac{I(\mathbf{x}) - A}{\max(t(\mathbf{x})^{\lambda}, t_0)} + A \tag{2}$$

In Eq. (2), the value of t_0 is set to be 0.1, and the transmission map $t(\mathbf{x})$ combines the geometric distance $d(\mathbf{x})$ and the medium extinction coefficient β (the net loss from scattering and absorption) into a single variable [14]:

$$t(\mathbf{x}) = e^{-\beta d(\mathbf{x})} \tag{3}$$

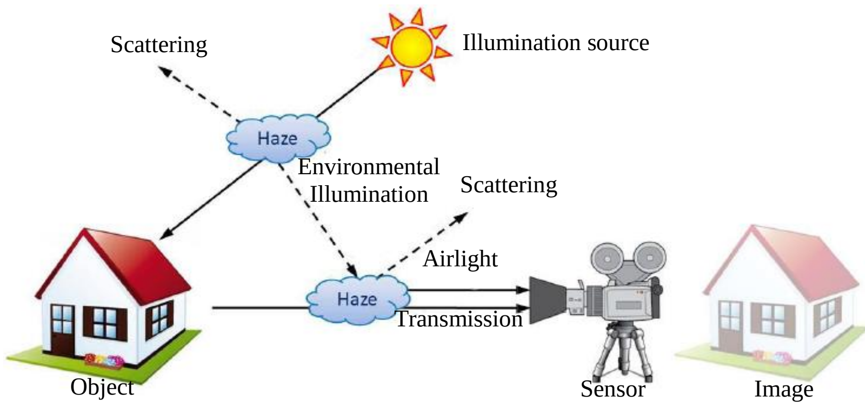
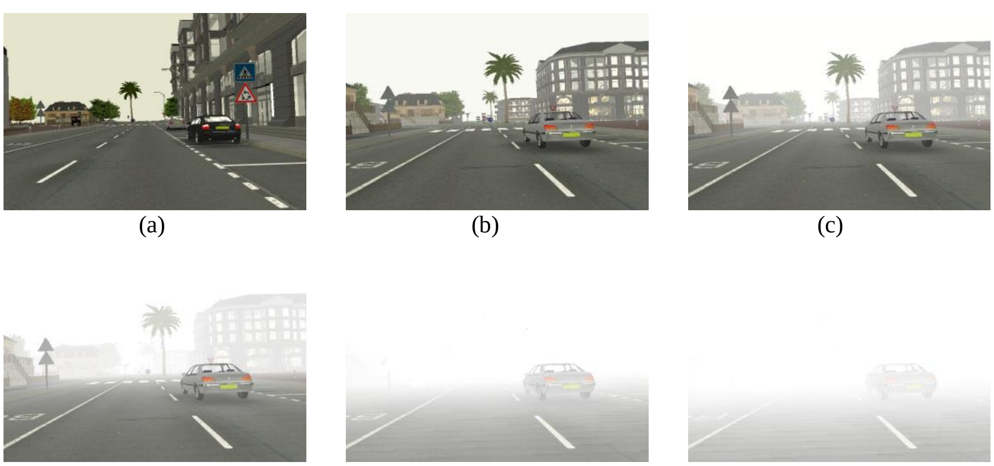


Figure 3. Scattering of light by atmospheric particles

Experimental results show that the simulated foggy scenes with different fog density can be created by adjusting the extinction coefficient β with the parameter λ in Eq. (2), that is $t^{\lambda} = (e^{-\beta d})^{\lambda} = e^{-(\lambda\beta)d}$. An illustrative example is shown in Fig. 4. As can be seen in the figure, the scene objects gradually become blur as the value of parameter λ increases from 0.6 to 25. Since different visibility distances corresponding to different foggy weather according to the international visibility grades [15, 16], we can thus simulate various fog effects by selecting proper parameter values. Tab. 1 gives the parameter values and the corresponding weather conditions for Fig. 4. One can clearly see that the simulation results are consistent with human visual perception by setting different λ value.



(a) (b) (c)

(d) (e) (f)

Figure 4. Different foggy weather simulations

Table 1. The parameter values and corresponding weather conditions for Fig. 4

Image	**4(b)**	**4(c)**	**4(d)**	**4(e)**	**4(f)**
parameter λ	0.6	1.8	4.0	15.0	25.0
weather conditions	Light haze	Haze	Light fog	Moderate fog	Thick fog

Therefore, by changing the value of extinction coefficient β using the fog's density factor λ, it is possible to control the visibility distance or the global field of view, which decrease when λ rises, and vice versa [17]. This conclusion is in consistent with the levels of the visibility grades and their corresponding extinction coefficient values that widely used in meteorology (see Tab. 2).

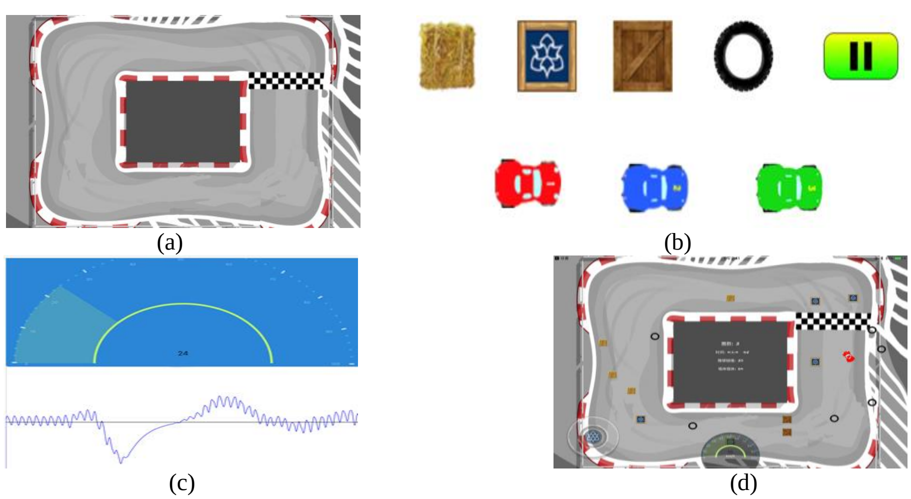
Table 2. International visibility grades with their medium extinction coefficients.

Grade	**Weather**	**Visibility distance**	**Extinction coefficient**	**Grade**	**Weather**	**Visibility distance**	**Extinction coefficient**
0	Dense fog	<50m	>78.2	5	Haze	2km-4km	1.960-0.954
1	Thick fog	50-200m	78.2-19.6	6	Light haze	4km-10km	0.954-0.391
2	Moderate fog	200-500m	19.6-7.82	7	Clear	10km-20km	0.391-0.196
3	Light fog	500m-1km	7.82-3.91	8	Very clear	20km-50km	0.196-0.078
4	Thin fog	1km-2km	3.91-1.96	9	Extremely clear	>50km	0.0141

3.3 Virtual racing scenario simulation

Different from the foggy scene simulation, the main control object of the virtual racing scenario is not the scene environment, but the moving racing car. The simulation system is developed by using the iOS 2D game framework - Sprite Kit, and the system includes four modules: data collection module, user input tracking module, game logical processing module, and data visualization module.

Among these modules, the data collection module collects the EEG data when users playing the racing game and transport the data to the mobile terminals. The user input tracking module allows users to control the orientation of the racing car by a virtual game handle. The game logical processing module includes the game setting arrangement [see Figs. 5(a) and 5(b)], collision detection of the racing car, the running time counting, the number of running laps and users' final score, etc. The data visualization module is also an important module for the BCI-based game. It receives raw EEG data from the MindWave headset and visually display the attention level value, which the raw data is displayed in the form of waveform and the attention level value is displayed in the form of a dial, as shown in Fig. 5(c). With all these modules, the virtual racing scenario game is created. Player can control the car speed with the help of the BCI-based speed dial which at the bottom of the user interface, as shown in Fig. 5(d).



(a) (b) (c) (d)

Figure 5. Racing scenario simulation

4. EXPERIMENTAL RESULTS

In our experiment, two criteria have been considered: (i) parameter adjustment, and (ii) qualitative evaluation. In our experiments, the fog simulation results are obtained by executing MATLAB on a PC, while the racing scenarios simulation is developed on iOS system and can be run on ipad.

4.1 Parameter adjustment

Our work features hardware and software that includes attention level computation and game effect control. Thus, the main parameters of the proposed methods are attention level value and fog control parameter or car speed control parameter.

In Neurosky's MindWave, the unsigned integer data reports the current attention levels of the user, which indicates the intensity of a user's level of mental "focus" or "attention", the high value occurs during intense concentration and stable mental activity. Distractions, wandering thoughts, lack of focus, or anxiety may lower the attention levels. Fig. 6 shows an example of attention level value when the experimental subject concentrates his/her attention or at distraction. As can be seen in Fig. 6, the value of attention level is generally above 50 when the subject is in concentration state and is below 50 when the subject is in distraction state.

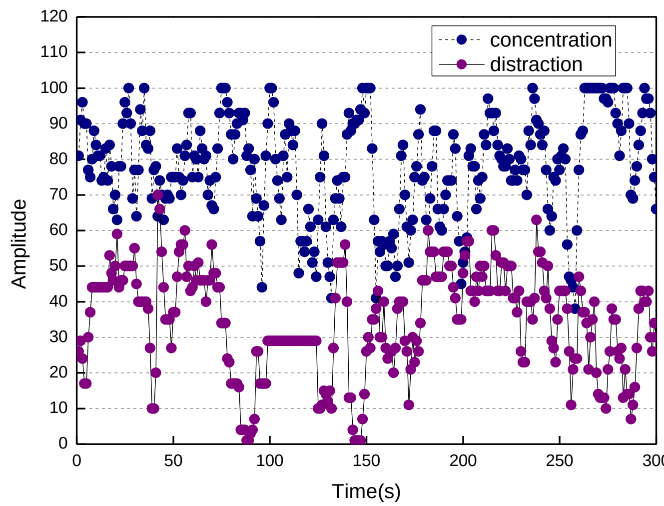


Figure 6. Example of attention level value in concentrate and distraction states.

We also find in our experiment that there is no reliable correlation between meditation level or eye blink and human concentrations, only the attention level is proved to be discriminative for human concentration and distraction. Therefore, we choose the value of attention level as our controlled parameter of the virtual game scenario, and this value ranges from 0 to 100. Specifically, when the attention value is between 40 and 70 means the intensity of a user's level of attention is in the middle range. When the attention value above 70 represents the attention intensity is relatively high, while below 40 means the intensity relatively low. Thus, for virtual foggy scenario simulation, different fog weather conditions can be determined by the predefined value range of attention levels, as shown in Tab. 3. Besides, based on the attention value av, the parameter λ can be estimated as:

$$\lambda = \left\lfloor \frac{av \times 10}{110} \right\rfloor \tag{4}$$

Table 3. Attention levels and corresponding weather conditions

	Value range of attention level and weather conditions			
Attention level	[0, 40]	[40, 50]	[50, 70]	[70, 100]
Weather conditions	Haze	Light fog	Moderate fog	Thick fog

For virtual racing scenario simulation, the attention value is used for starting the game and controlling the speed of the racing car. Specifically, when the attention value is above 50, the racing game begins. Then, the speed of the racing car can be determined by the eight times amount of attention value. Tab. 4 shows some examples of attention value and corresponding speed value. As can be seen in Tab. 4, the attention value can be directly transformed into the car speed in this way. The more concentrate the users are, the faster speed of the car will be. Thus, a BCI-based racing scenario is created.

Table 4. Attention value and corresponding car speed

	attention level value and car speed			
Attention level	30	61	75	100
Car speed	240 km/h	488 km/h	600 km/h	800 /h

4.2 Qualitative evaluation

4.2.1 Qualitative evaluation for foggy scene simulation

A set of no-fog synthetic images from the database FRIDA [18] are used in our experiment. These images are generated from various viewpoints trying to sample as many scene aspects as possible. In our experiment, each image is size of 300×225, and two generated foggy scenes are shown in the first row of Fig. 7. For each no-fog image, its associated transmission map is also provided by the database, and the map is required to add fog in the input no-fog images. Thus, the BCI-based virtual scenes with a uniform fog added can be generated. Meanwhile, the attention values obtained by MindWave headset are also displayed in the second row of Fig. 7. One can clearly see that when the attention value is 29, the parameter is 2 according to Eq. (4), and the corresponding weather condition is haze. When the attention value is 91, the parameter is 8, and the weather is thick fog accordingly. This confirms our observations on Fig. 7 and Tab. 3.

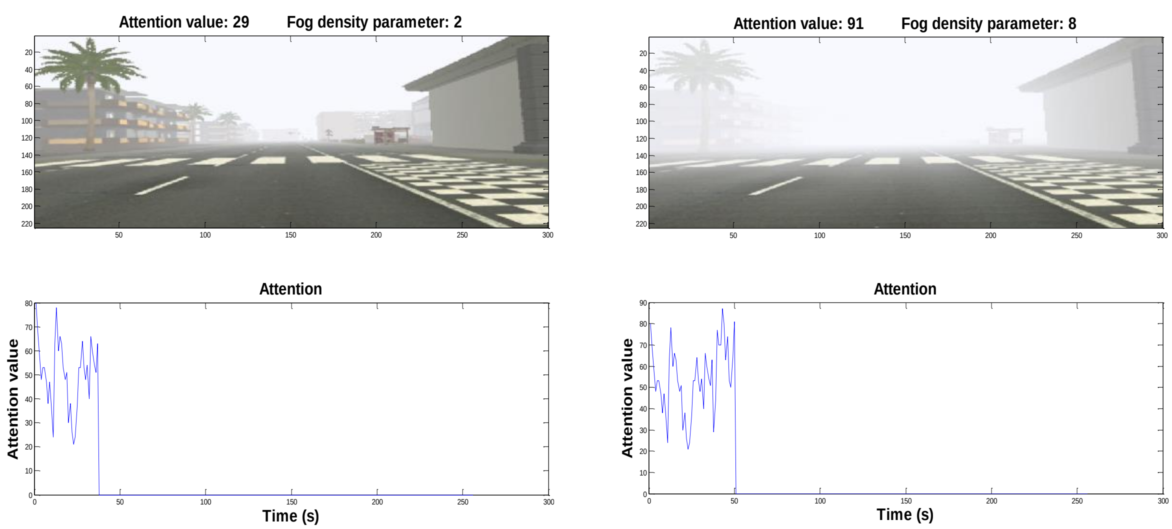
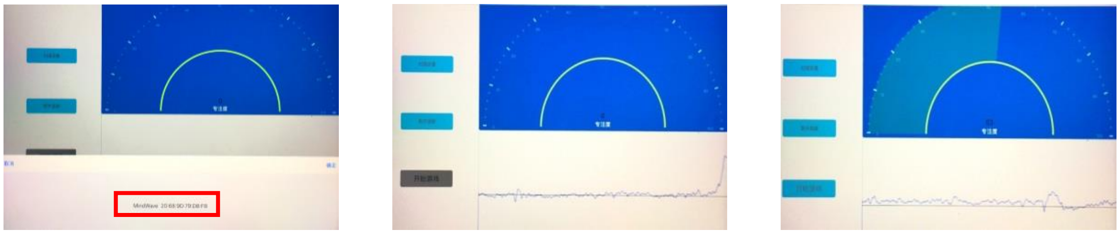


Figure 7. Simulated virtual foggy scenes for synthetic images.

4.2.2 Qualitative evaluation for racing scenario simulation

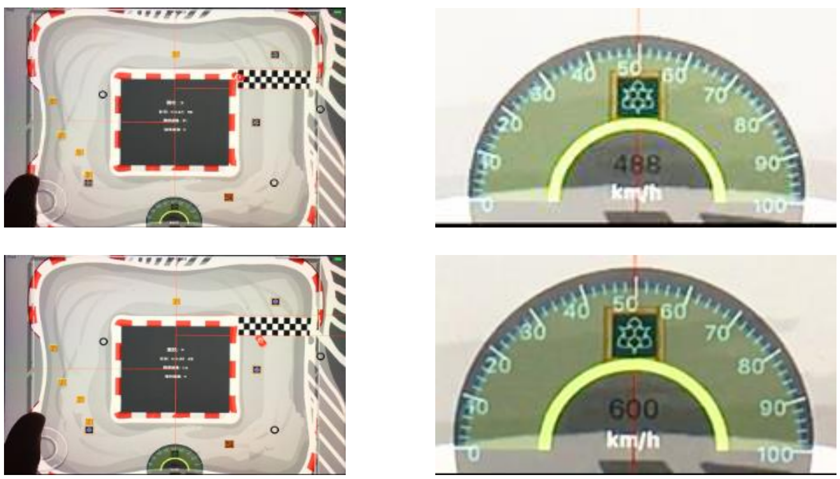
The racing game is started by the concentration control signal. As can be seen in Fig. 8(a), the game system first scans the device to find the MindWave headset. During the device connecting process, users can press a button to disconnect the EEG signal connection at any time. The finding result of device MindWave is shown in the red rectangle in Fig. 8(a). Thus, the attention level data can be collected by the headset for starting the game. Next, a threshold value is set to determine whether to start the game. When the attention level is below 50, the game start button is unavailable, as shown in Fig. 8(b). Once the attention level is above 50, the start button become available, and users can press the button to play the game, as shown in Fig.8(c).



(a) (b) (c)

Figure 8. User interface for starting the BCI-based racing game.

Then, a user interface of the racing game appears, as shown in Fig. 9(a). Players can control the speed of the racing car using the attention level obained by the MindWave headset. When the car speed is 488 km/h which corresponding to the attention value 61, the running time is 38 seconds. While when the car speed is 600 km/h which corresponding to the attention value 75, the running time is only 24 seconds, as shown in Fig. 9(b). According to our observations, the attention value 61 means the user's attention is not very concentrated, and the attention value 75 means the user is focusing his or her attention now. The higher the attention intensity, the faster the car speed and the less time the car spends to run a lap. Since the game is controlled by the attention level, thus many applications, such as concentration training and flexibility training, etc., can benefit from the BCI-based racing game.



(a) (b)

Figure 9. Racing scenario simulation with different car speed.

5. CONCLUSION

In this paper, we have proposed an efficient method to generate virtual game scenario by using brain computer interface. Our method benefits much from the attention level value computed by the Thinkgear chip in Neurosky's MindWave headset. This EEG sensor, together with the atmospheric scatting model or the 2D game framework, is applied to control the fog density or car speed of the virtual scenario. Experimental results show that the proposed method can generate quite visually pleasing game scenario with good sense of reality and immersion.

However, using brain wave signals to control virtual scenario is not an easy task since it faces many challenges. For example, the EEG sensor data sometimes fluctuate wildly. Because of this fluctuation, the generated virtual foggy images or racing car speed may sometimes change too rapidly. Besides, the attention values from the MindWave headset come slightly delayed as well. Nevertheless, we provide a new way to generate virtual game scenario based on an EEG sensor, which may not only bring fresh game experience to players, but also assist patients or elderly people to recover their mental strength and helps children to train their concentration in educational environments. In the future, we intend to investigate more effective transmission estimation method to make the simulated foggy results more close to the real fog situation, and design more rational interface of car racing game to display the EEG sensor data in real time.

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AUTHORS' BACKGROUND

Your Name	Title*	Research Field	Personal website
Fan Guo	lecture	Image processing, virtual reality	

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