Development and Application of Virtual Reality Immersive Learning System for Biology Subjects

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Abstract. In traditional biology education, there are many abstract biological models and phenomena. However, the traditional classroom teaching format often fails to vividly and concretely present knowledge, making it difficult for students to imagine and leading to difficulties in understanding. Virtual reality technology addresses this issue by constructing an immersive learning environment, providing learners with three-dimensional visualizations and immersive interactive experiences of biological processes. This approach makes knowledge more tangible, aiding learners in better understanding biological concepts. This study focuses on the nervous system as a classic case, creating an immersive learning environment. In addition to building realistic scenes, various interactive features such as joystick interaction, scene roaming, and automatic audio explanations have been implemented. These functionalities, spanning from the macro to the micro level, assist learners in comprehending the structure and functional characteristics of the nervous system.
CCS CONCEPTS • Applied computing~Education~Interactive learning environments

Keywords: Virtual Reality (VR), human-computer interaction, scene roaming, immersive learning, nervous system

1   Introduction

In the biological science curriculum, there are many fundamental concepts related to morphology, structure, and physiological phenomena, most of which are essential content in high school biology. Traditional demonstration teaching methods can generally meet the requirements for presenting knowledge in a visually intuitive way. However, when it comes to practical or microscopic and abstract teaching content, students often lack sufficient abstract thinking abilities, leading to difficulties in understanding. To cultivate students' practical innovation, self-learning ability, and exploratory spirit, immersive learning based on virtual reality can drive a transformation in teaching methods and enhance the quality of biology education.Virtual reality technology is utilized to recreate experimental facilities and environments or provide immersive experiences of tangible biological phenomena, holding immense potential for applications in biology education[1-2]. Relevant studies indicate that virtual biology learning environments created through virtual reality technology have an overall positive impact on students' cognition, skills, and learning motivation[3-5].

2   METHOD

2.1   Scene construction for the nervous system and nerve cell

The nervous system and nerve cell models were constructed with 3ds Max and ZBrush software, as shown in Figure1.
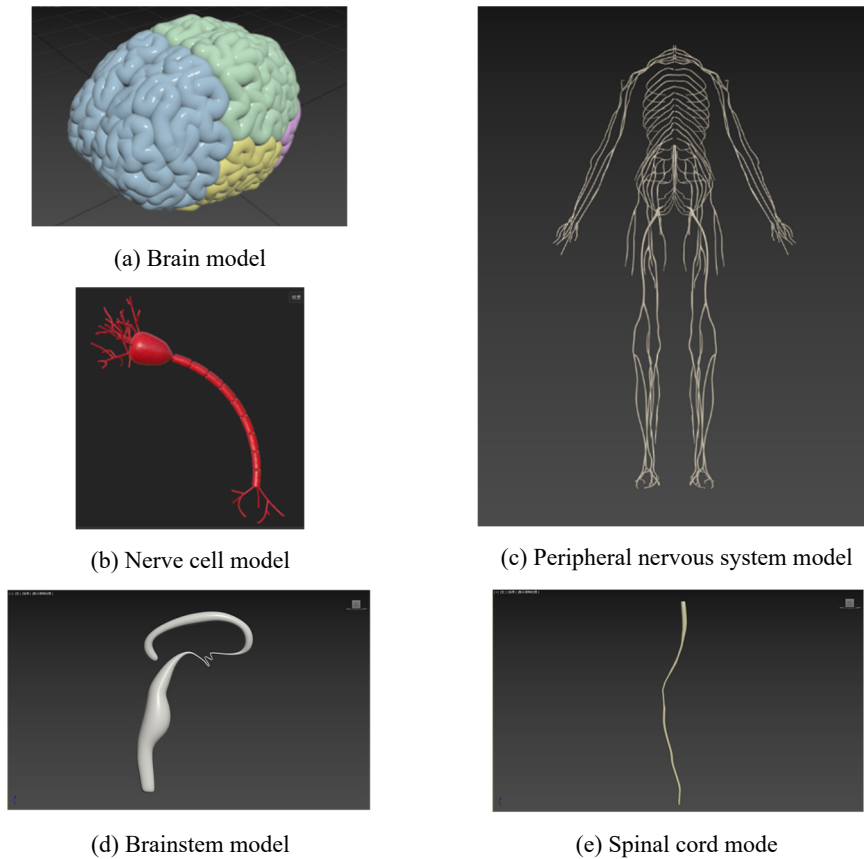

(a) Brain model

(b) Nerve cell model

(c) Peripheral nervous system model

(d) Brainstem model

(e) Spinal cord mode

Figure 1: Model of the nervous system

2.2   Scene Construction in Unity3D

2.2.1 Build VR projects based on Unity URP templates

Step1. Create a new Unity URP project, then download and import the SteamVR plugin.

Step2. In the Assets directory of the Project panel, right-click the blank area of the Project panel, choose the Scene subitem of the Create menu item from the pop-up menu, and create a scene named Main.

Step3. In the Project panel, create a folder named "NervousSystem" under the "Assets" directory to house the resource files for this case.

Step4. Double-click to open the Main scene, drag the VR camera (the "[CameraRig]" prefab in "Assets\SteamVR\Prefbas") into the Main scene.

2.2.2 Import models and textures

Taking the nerve cell model in the case as an example, the methods of model import and material addition are introduced.

Step1. Copy the neural cell model file "nervecell.fbx" to the "Assets\ NervousSystem" directory under the project folder, the ".fbx "file will be used as a Prefab, drag it into the" Main "scene, you can start the interaction design.
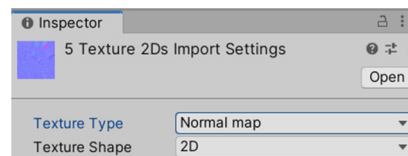
Step2. Create the "Map\NerveCell" path in the "Assets\ NervousSystem" directory and copy all the maps of the nerve cells under this path.

Step3. Set the map size. Select all maps in the "NerveCell" folder, set the "Max Size" attribute (" 4096 "or" 8192 ") in the "Inspector" panel, and click the "Apply" button to apply the Settings(Figure 2(a)).

Step4. Set the normal map type. Select all Normal maps in the "NerveCell" folder (ending in "_norm.png"), set the Texture Type attribute to "Normal Map" in the "Inspector" panel, and click the "Apply" button to apply the Settings (Figure 2(b)).
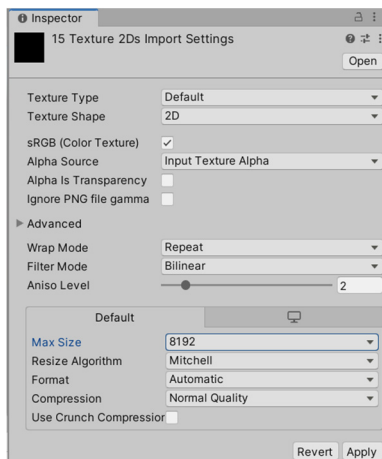
(b) Map type

(a) Map size

Figure 2: Set the map size and type

2.2.3 Add material

Step1. Create the "Material" folder in the "Assets\ NervousSystem" directory to place the Material ball. Right-click the blank area in the "Project" panel and select the "Material" subitem of the "Create" menu item from the pop-up menu. Create a new "URP/Lit" material ball and name it "body".

Step2. On the Inspector panel, set Surface Type to Transparent. Then the "body" model in the "NerceCell"   folder   "Nervecell_body_AlbedoTransparency.png",

"Nervecell_body_MetallicSmoothness.png" and "Nervecell_ "body_Normal.png" to the "Base Map", "Metallic Map" and "Normal Map" boxes in the Inspector panel respectively. The self-luminous effect of the "body" material was enabled by checking the "Emission" check box, and the self-luminous color was selected at "Emission Map". In this example, the RGB value of the selected color was (60,0,0), so that the model emitted red light.

Step3. As shown in Figure 3, drag the "body" material ball to the "body" subobject of the "Nervecell" game object.

Step4. Repeat the above steps to create material balls with corresponding names for each structure of the "Nervecell" game object, and drag them to the corresponding sub-objects of the "Nervecell" game object, and finally get the nerve cell model in the "Scene" interface as shown in Figure 3.
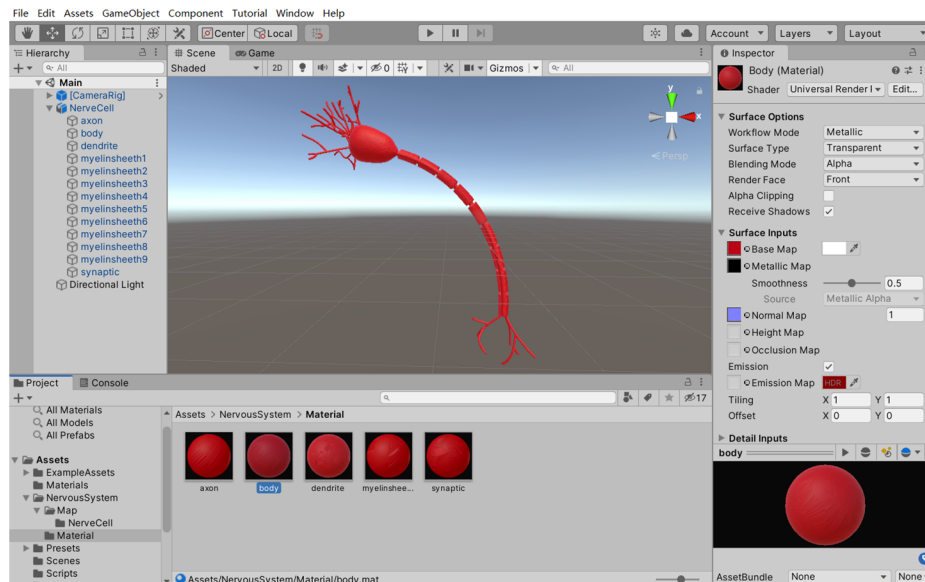

Figure 3: Add material

2.2.4 Scene layout

Import and add models and materials such as nervous system, fence, display board, etc. After adding material balls to the model, use translation, rotation, scaling and other operations to place the model and arrange the virtual scene.

2.2.5 Add light

The Point Light source "Point light" is created above the nerve cell model to simulate the lighting conditions of the science and technology museum, so that the nerve cell model is illuminated. As shown in Figure 4, the parameters "Range", "Color", and "Intensity" of the light can be set in the Inspector panel.
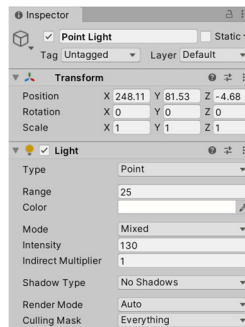
Figure 4: Light source setting parameters

2.2.6 VR scene roaming

Step1. Configure buttons on the controller. In this case, only four directional keys and Trigger keys need to be configured, namely, the upper key N (North), the lower key S (South), the left key W (West), the right button E (East), and the trigger key T (Trigger) on the handle trackpad. The trigger button is used for subsequent handle interactions.

Step2. Add scripts to control camera movement. Create a C# script "Main.cs" and mount it to the [CameraRig] preform. In the Update() function, determine the position (N, S, W, or E) from which the user pressed the button, and Translate() in that position by a certain distance.

2.2.7 Handle interaction function

Learners can interact with the nervous system by selecting buttons located on the display board through the rays emitted by the handle - highlighting the corresponding structure, introducing information on the handheld information board, and playing audio of related knowledge.It is implemented by C# scripting language, and its flow chart is shown in Figure 5.
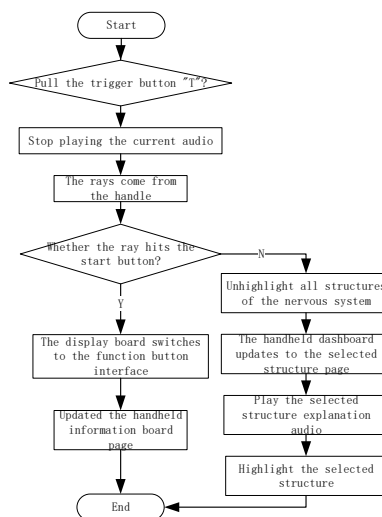

Figure 5: The script flow chart of the nervous system

2.2.8 Nervous system and its structural unit

Based on the above steps, this study takes the "nervous system" as an example to design and implement an immersive biology learning environment, showcasing relevant knowledge about the nervous system and its structural unit, the nerve cell(Figure 6).
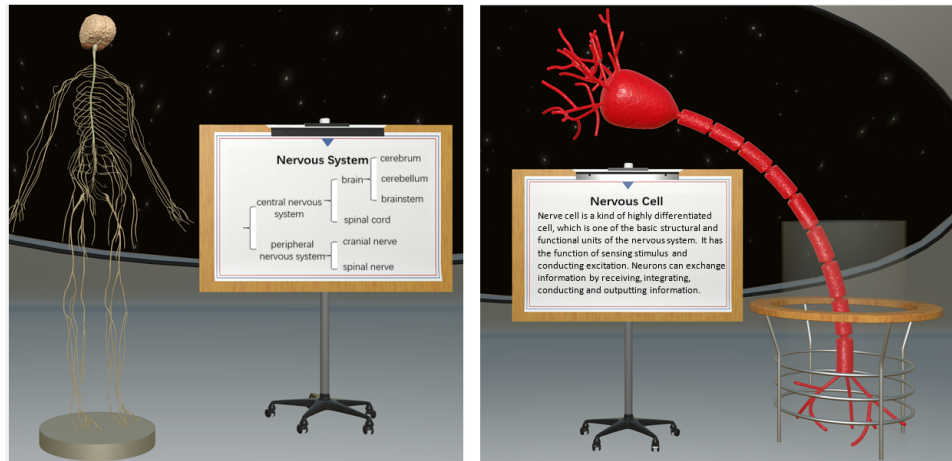

Figure 6: Immersive biological learning system based on the nervous system

3   Results & Discussion

3.1   User evaluation experiment

The immersion, authenticity, attractiveness, operability of interactive functions and teaching effect of the immersive learning system environment were evaluated. Questionnaires and physical immersive learning environment evaluation experiments were used as shown in table 1.

30 high school students from Beijing Experimental School and 20 college students from Beijing Normal University, covering different ages, genders and learning stages, were selected as subjects in the evaluation experiment and made comprehensive and accurate evaluation of the immersive learning environment from different perspectives. Figure 7 shows subjects evaluating our immersive learning system.The results of quasi-experimental data analysis are shown in table 2.

Figure 7: Subjects are experiencing the immersive learning system

3.2   Result analysis

As shown in Table 1, in terms of immersion and interestingness, 80% of the subjects agree or strongly agree that they are fully integrated into the experience of the virtual environment. 70% of the subjects agreed or strongly agreed that it was very real and interesting. Most of the subjects think that they can integrate into the immersive learning environment more naturally, and think that it has a certain sense of reality and fun.In terms of interactive functions, 80% of the subjects agree or strongly agree that they can move and interact proficiently in the scene at the end of the experience, and 75% agree or strongly agree that they can easily use interactive functions.In terms of teaching effect, 90% of subjects think that interaction makes the learning process more interesting, and 75% of subjects think that they can focus on learning tasks.

Table 1. A questionnaire on the immersive learning system in biology

Questions	Strongly agree	Agree	Not always	Not agree	Strongly disagree
1.I was completely immersed in the experience of the virtual environment.	40%	40%	15%	5%	0%
2.Very real and fun in an immersive learning environment.	55%	25%	15%	5%	-
3.By the end of the experience, I could vary adept at moving and interacting with the scene.	50%	30%	15%	5%	0%
4.I could easily use the interactive features.	65%	10%	20%	5%	0%
5.I think interaction makes learning more interesting	70%	10%	10%	-	-
6.I was able to focus on my study tasks.	60%	15%	25%	0%	0%

Then ANOVA of multiple factors was used to analyze the influence of different experiment tasks (see Table 2). In Table 2, Factor A referred to the different experiment tasks and Factor B referred to whether VR system was enabled. Among them, factor A has no obvious influence on learning effect, but factor B has significant influence on flow experience and various experimental indicators. It shows that VR biological system can enhance learning effect and experience.

Table 2. Result of multiple ANOVA

Factor		Flow experience	Memory	Comprehend	Experiment	Total
Factor A	F value	0.606	7.586	2.492	4.506	8.337
Factor A	p value	0.439	0.007	0.119	0.037	0.005
Factor B	F value	11.454	51.311	13.896	37.566	70.772
Factor B	p value	0.001	0.000	0.000	0.000	0.000

4   Conclusion

Through the questionnaire survey, the following information is obtained: the learning environment presented by the immersive learning system is more realistic, users can move naturally and skillfully in the scene, interactive operations are easy to learn, and they can freely interact with the model in the environment after simple instructions. And the interactivity of the learning system increases the interest of the learning process, and the users can be more focused on learning, which has a good teaching effect. It is suggested that the visual effects of the learning system should be further optimized, such as clearer pictures, more refined models, etc., and interactive functions should be further improved, such as adding instructions for interactive operation and roaming inside the model. In short, most subjects believe that immersive learning system scenarios can better meet the needs of learners.

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