Implementation of an effective locomotion technique in Virtual Reality Stress Therapy

Imran Mahalil[1,2], Azmi Mohd Yusof[1], Nazrita Ibrahim[1,2], Eze Manzura Mohd Mahidin[1,] Mohd Ezanee Rusli[1]

[1]*College of Computing & Informatics, Universiti Tenaga Nasional*
[2]*Institute of Informatics and Computing in Energy, Universiti Tenaga Nasional*
Putrajaya Campus, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia
[3]*UNITEN R&D Sdn. Bhd*
Email- {ImranMahalil, azmiy, nazrita, ezanee, ezemanzura}@uniten.edu.my

***Abstract*—This paper discusses the issues and difficulties faced during the development process of several locomotion techniques that focuses on a Virtual Reality-based stress relaxation therapy. During the process, three techniques are developed and tested. These three techniques are joystick controller-based navigation, guided navigation and teleportation techniques. For each technique, the problems faced include the compatibility issues between the hardware and the software, scripting difficulties, game engine, and neural conflict and all these issues are also addressed in this paper. The discussion does not only highlight the problems faced but also suggests several solutions. In general, the objective of this development is to determine the most effective locomotion technique under the domain of VR stress therapy for relaxation. Research elements studied during the development includes determining the best technique that reduces or eliminates motion sickness during locomotion. This proposed technique is the novelty of this research. For this purpose, various locomotion techniques are studied and developed which is later used under a domain of stress therapy. Note that this research focused on issues related to the locomotion technique rather than the aspect of creating the virtual environment.**

Keywords—Virtual Reality VR), locomotion, teleportation, stress therapy

I. INTRODUCTION

Virtual reality is technology that provides an immersive feeling to users in which individuals are convinced that what is being experienced is reality [1] (John Vince - Introduction to Virtual Reality). One of the applications of VR is in stress management. Although it is proven effective [17], there are still some issues needed to be addressed. One of the issues is navigation, which if not handled properly will cause motion sickness that will prevent users from fully benefiting from the system. We have developed a VR-based application called VRelax, which is used to reduce stress by relaxing through the use of a VR application. Basically, there are two main elements that have been incorporated in this application, namely, typical Malaysian environment in 3D, and soothing audio. By incorporating these two elements, a VR-based system for stress therapy that is able to produce a realistic and immersive relaxing world is developed. However, this VR technology is not perfect yet as several problems is still yet solved. These problems often lead to a situation where maximum immersive experience cannot be gained. Among those problems are lack of realism, imperfect device of human sensor, and unrealistic interaction technique used in the VR.

The first problem is lack of realism which refers to a situation where the visualized graphics are not realistic. To create a high graphic effect, the type of graphic processing unit (GPU) plays an important role where rendering for high quality graphics requires high resources.

The second problem is related to the inequality between the five human sensors and the devices being used. In real life, human depends on five senses which are sight, hearing, taste, touch and smell. However, at the moment, there is still no available technology particularly one for tasting, touching and smelling generates the same effect. This reduces the level of immersiveness.

The third problem that hinders the best performance output while using virtual reality application is related to the interaction process including the input and output, as shown in Figure 1. Input is divided into tracker, navigation, audio, retina and gesture; whereas output is divided into audio, visual, haptic, as well as taste and smell. Under input there is navigation, and under navigation is the technique of locomotion [2]. However, this paper only focuses on the navigation and visual effect.

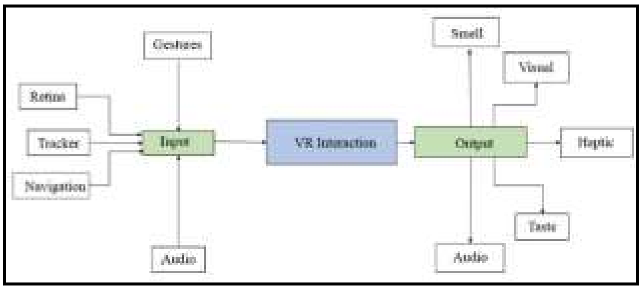

Fig. 1. VR Interaction flow

There are three types of locomotion techniques often used while navigating in a virtual world and these techniques are walking-in-place, controller or joystick-based, and teleportation [1]. The type of locomotion applied affects the level of users' immersion while navigating in the virtual world [2].

The first type of locomotion technique is called walking-in-place which is also known as motion-based [3]. Motion-based locomotion uses direct input from the users' body, through the senses from the virtual reality hardware to provide digital feedback to the computer to create movement into the virtual world, for example of the motion; swimming, climbing, cycling and etc [4].

Figure 2 illustrates the walking-in-place by using a cycle to move from one point to another. The continuous physical

978-1-7281-3944-9/19/$31.00 ©2019 IEEE

motion of the users' leg enables the user to move in the virtual world.

Fig. 2. Walking-in-place motion locomotion using leg motion

The second type of locomotion is by the use of controller such as joystick. When using controllers or joystick, users interact with the virtual world by pressing buttons available on the controller [5] [18]. When the button is pressed, the camera or avatar in the virtual world would move in the direction directed by the button. This type of navigation is suitable for car driving, flight simulation, gaming application etc. Figure 3 shows an example of a controller often used for locomotion.

Fig. 3. A controller-based locomotion using buttons

The third type of locomotion as mentioned by Boletsis known as teleportation. Note that in this teleportation technique, controller or joystick is also used. However, the way user navigates inside a virtual world is different from the second type. Teleportation is a fast level of navigation where the user visually 'jumps' from one location to the next instantly. When using a Head-Mounted Display HMD), this type of locomotion technique imparts significantly fewer feelings of motion sickness on the user, in addition to being fast and easy to operate [6] [17].

Teleportation technique can be divided into four categories. Each of this category is explained in more detail under 'locomotion integration challenges' [1] [7] [16].

1. Point-and-click without barrier, also known as free teleport to any location using button where teleporting is done on their command. In this technique, when a button is pressed, an indicator will appear on the visualized world that shows the point where the user will be teleported to. For example, if the user sees a big rock and then clicks on a button visible on that rock, a highlighted beam will appear and the user is instantly teleported to the big rock.
2. Fixed destination is a technique where the locations are fixed at a various point inside the virtual word. When users press a button, the users can only teleport to the available points.
3. Point and click with barriers, this type of teleportation is where the users are allowed to determine the destination but within the specific area in the virtual world. For example, users are not allowed to go beyond a mountain cliff that is visible in their view. Virtual boundaries are created to stop the users from reaching or entering a certain part of the virtual world.
4. Gaze-directed locomotion. Gaze-directed locomotion is used for VR mobile applications due to lack of hardware controllers to navigate through the virtual world. For example, in a mobile application, if a user wants to open a virtual door, he can stare at the doorknob and it will teleport the user into the room.

By using the correct locomotion technique while navigating inside the virtual world, it can create a more realistic and immersive experience. These locomotion techniques and factors to determine its suitability can be summarized in the following table 1 [1].

TABLE I. VIRTUAL REALITY LOCOMOTION TECHNIQUE

	Interaction Type	VR motion type	VR interaction space	VR locomotion types	Prevalent technique
VR locomotion technique	Physical	Continuous	Open	Motion-based	Walk-in-place
			Limited	Room-scale-based	
	Artificial	Continuous	Open	Controller-based	Controller/Joystick
		Non-continuous		Teleportation-based	Teleportation

The first factor as in Table 1 is the Interaction type. There are two interaction types; physical and artificial. Physical refers to a situation where users' own body movement performs virtual locomotion. On the other hand, artificial refers to the interaction where gazing is used to interact with the virtual reality system [1] [9].

The second factor is a VR motion type. Under VR motion type, it is classified as 'Continuous' and 'Non-continuous'. Continuous means that the user would have to perform a certain task continuously, for example pressing a button or physically moving a body limb. The second classification is Non-continuous which refers to a single task or click would enable the VR motion. For example, in a cycling VR application, the user has to paddle continuously in order to move from one point to another. Whereas in a non-continuous type used in a flight simulator cockpit; navigation is performed by a single click of a button [10].

The third factor is on the interaction space. Generally, virtual reality is played in an open space area within the sensor's parameter. However, some VR application is used in a limited space. For example, a CAVE system where it is a room-scaled based, that limits the interaction within a certain confined area. This confined concept is also applied to a flight simulation in a flight cockpit, formula One racing cockpit and etc [7] [11].

Lastly, as shown in Table 1, the last column is categorized as the VR locomotion types. The technique applied for locomotion is determined by the type of devices available and the type of environment created.

II. LOCOMOTION INTEGRATION AND DEVELOPMENT

In this section, several challenges and solutions encountered during the development of VRelax system are explained in detail. It includes how the camera is manipulated and how parameter values are tested which eventually affects the vision as well as the locomotion of the system [12]. Unity game engine is used during the development. The explanation below focuses on how the hardware and the software (game engine) are integrated. In addition, methods on developments achieved and tests conducted for each technique were also discussed.

A. Hardware and software

The overall specification of the hardware is shown in Table 2.

TABLE II. HARDWARE SPECIFICATIONS

Earlier stage			Final stage		
Graphic Processing Unit (GPU)	Central Processing Unit (CPU)	Installed memory (RAM)	Graphic Processing Unit (GPU)	Central Processing Unit (CPU)	Installed memory (RAM)
GTX1070 (8GB GDDR5)	Intel i7-7700 3.60GHz	16GB DDR4	GTX1080 (1048GBs)	Intel 9-8950HK 2.90GHz	32GB DDR4

As shown in Table 2, the hardware specification fulfils the requirement needed to run Oculus Rifts' devices. Table 2 also shows that the hardware specification in the earlier stage is different than the final stage. It is discovered that the improvement from GTX 1070 to GTX 1080 has a significant impact to the quality of the graphics. The loading time is also found to be shortened with the increase of the RAM. During application development, the hardware used for viewing the virtual world is an Oculus Rift consumer version 1 (CV1) that comes with a controller. This device is selected due to its design and integration prospect to the selected game engine (i.e Unity). The size of the controller is smaller than other brands.) It is comfortable to hold and easy to use as shown in Figure 3. During the development of a virtual world and locomotion techniques, Unity 2018.1.1f1 is used as the game engine. The following sections also explain further on the advantages and disadvantages of each technique.

B. Joystick or controller-based navigation

The first technique of locomotion is by using joystick and controller. Using joystick, the movement of direction is controlled by the user, as shown in Figure 4. By pushing the controller or joystick arrow button forward, backward, left or right, the user will hence, move into that direction.

Fig. 4. Technique one: Joystick or controller-based navigation

The integration of a joystick with Unity was done by downloading the Oculus driver. It then requires setting up the wireless Oculus touch controller. This integration process is considered easy. The controller is plug and play in Unity, which means that it will automatically be run by the Oculus driver with a free asset called Virtual Reality Tool kit (VRTK). This VRTK is available in the Unity asset store. VRTK also comes along with all the features and plugins that enable Oculus to interact with many other hardware [1] [13] [14]. Figure 5 shows a Unity VRTK from the asset store. This asset consists of the components necessary to enable the hardware device to run when the virtual reality application is built into an executable file. This asset store is a library where developers who uses Unity can purchase or acquire the assets. VRTK asset is a plugin that uses C# scripts to run various virtual reality devices such as High Tech Computer Corporation (HTC) vive, mobile devices and Sony VR.

Fig. 5. Unity virtual reality asset

In order for this technique to function, it has to go through a simple process. As shown in Figure 6, the interface for manipulating the camera is provided. This parameter is called Gizmos.

Fig. 6. Illustrates the parameter of the VR camera in Unity

Under the "Scene Camera" the value for Field of View (FOV) is set to 90. The number 90 indicates how much the virtual world can be viewed at any one time. For Oculus CV1, the suggested FOV is 90 and the dynamic clipping is turned on [14] [8]. Dynamic clipping is suggested to turn off in a situation where the world is small. The next parameter adjusted throughout this development is the camera speed. This parameter determines the pace of the camera moving inside the virtual world. When developing, we observed that when using the joystick or controller, the slower speed causes some users to lose interest since travelling from one destination point to another will take a long time. However, high speed in the virtual world causes some users to experience motion sickness. This is similar to findings from [9] [10] [11] [15] that supported the findings of moving in a VR application causes motion sickness. When testing this navigation technique with VRelax system at high speed, it has caused the users to feel dizzy. This is against the objective of VRelax which is to make the users feel calm and relax. To avoid motion sickness while undergoing relaxation stress therapy, it was noted to use a different method of locomotion technique.

C. Guided camera navigation

The second technique tested is called guided camera navigation. This technique is not specifically mentioned in Costas Boletsis's prevalent technique. This technique however is useful to create a motion for a specific type of VR world aimed for viewing only. In this technique, the camera is setup in a manner that it will move along a specified path. In this technique, the camera also moves automatically by itself. The virtual camera and the view seen by the users are moved based on the timer applied to a pre-set path to the destinations. While moving, users are free to view the surrounding environment by changing the head orientation. Figure 7 shows the setup combination of the navigation technique.

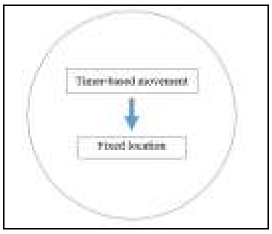

Fig. 7. Technique two: Timer-based and preset path navigation

In order for this technique to function, it has to go through a simple process. As shown in Figure 8, the interface for manipulating the camera is provided. This parameter is called Gizmos. Under the "Scene Camera" the value for Field of View (FOV) is set to 90. The number 90 indicates how much the virtual world can be viewed at any one time. For Oculus CV1, the suggested FOV is 90 and the dynamic clipping is turned on [14] [8]. Dynamic clipping is suggested to turn off in a situation where the world is small. The next parameter adjusted throughout this development is the camera speed. This parameter determines the pace of the camera moving inside the virtual world.

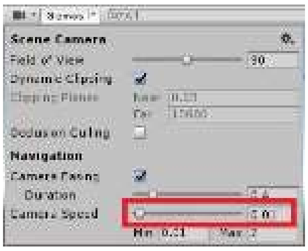

Fig. 8. Represents the parameter to change the camera speed

When testing this navigation technique with a VRelax system, a few weaknesses are discovered. The first weakness is that, this technique does not give the users a freedom to a destination that they want. Second weakness is that some users are anxious to move faster while the system has fixed the movement speed. The third weakness is when the user desires to stay longer and enjoy a certain view; the system would automatically move them based on the timer. Thus, all these three weaknesses could create stress instead of helping them relax. In general, as observed, the disadvantage of using this technique is that the camera movement can cause unpleasant experience and is difficult to set the speed value that is appropriate for the majority of users. There is no suitable speed that is relaxing to the users when used for relaxation in a VR-based application [17]. Another disadvantage is that the users are forced to go through the predefined path and look at certain objects that they are not interested in while the camera is moving in the virtual world.

From these first two techniques, we decided that navigation involving speed might not be suitable in the use of VR based therapy for stress. This is due to the nature of the treatment that aims for the users to relax. However, higher speed might cause motion sickness while slower speed might cause the users to get bored, since getting from one point to another is taking too long. This finding is similar to research conducted by other researchers [9] [10] [11] [15] in different domains of VR other than relaxation causing motion sickness. Due to the highlighted issues encountered when using guided camera navigation technique, the third locomotion technique being applied is by using teleportation.

D. Teleportation technique

We developed two versions of teleportation technique. The first version is free teleportation navigation technique. However, we recognized an issue of tendency for users to go out of the developed virtual environments. Therefore, we came out with the second navigation technique which is fixed destination teleportation.

1. Free teleportation navigation

The first version of teleportation technique developed is called free teleportation navigation. For this technique, users use a controller to teleport to any parts of the virtual world without limitation; the setup is as shown in Figure 9.

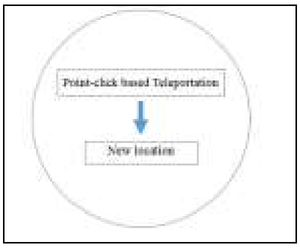

Fig. 9. Technique three: Point-click based teleportation navigation

Teleportation happens almost in an instant once the button is pressed. As shown in Figure 10 and Figure 11, a ring is displayed to the user to indicate where they are teleporting.

Fig. 10. First ring type

Fig. 11. Second ring type

As continuous testing is done, five main issues are observed. The issues are as follows:

- The ring is not always visible depending on where the laser is pointed to.
- As the ring is not visible to the user, the user does not know where they will be teleported; hence this caught them by surprise when they are suddenly moved to a new location (although they are the one who pressed the teleport button). This may cause the user to feel less realistic. Since realism is one of the key to the presence felt in virtual reality system, therefore, it is advisable to increase the realism effect.
- Users are stuck because they cannot move or navigate to another point. This situation occurs in certain places in the virtual world where users are required to turn their body around to point and click to a desired location. Due to this requirement where physical turning is required, user may experience a feeling of being in discomfort. This difficulty is more extreme when users are in a sitting position.
- Instantaneous transfer may reduce the realism effect. When a user moved instantaneously, they experience spatial disorientation simulation sickness. In order to solve the fourth issue, a fade in and fade out process of half a second is applied before users are teleported to a new location. The fade out process is applied to the current location while fade in is applied to a new location. This whole process is handled by using a code. A snapshot of a code is shown in Figure 12. This solution reduces the discomfort level of the user due to spatial disorientation.
- The suitable type of ring to be used when user presses a button.

```
private float lastInterval;
private float elapsedTime;
private bool timerStarted;
private float waitTime = 1;
[Tooltip("Fade duration")]
public float fadeTime = 2.0f;
[Tooltip("Screen color at maximum fade")]
public Color fadeColor = new Color(0.01f, 0.01f, 0.01f, 1.0f);
public bool fadeOnStart = true;
public int renderQueue = 5000;
private float uiFadeAlpha = 0;
private MeshRenderer fadeRenderer;
private MeshFilter fadeMesh;
private Material fadeMaterial = null;
private bool isFading = false;
public float currentAlpha { get; private set; }
void Awake()
{
    // create the fade material
    fadeMaterial = new Material(Shader.Find("Oculus/Unlit Transparent Color"));
    fadeMesh = gameObject.AddComponent<MeshFilter>();
    fadeRenderer = gameObject.AddComponent<MeshRenderer>();
    var mesh = new Mesh();
    fadeMesh.mesh = mesh;
    Vector3[] vertices = new Vector3[4];
```

Fig. 12. Fade in fade out code

The type of the ring being displayed is determined by the parameter Bean Rotator, as shown in Figure 13. This setup comes with downloaded VRTK asset.

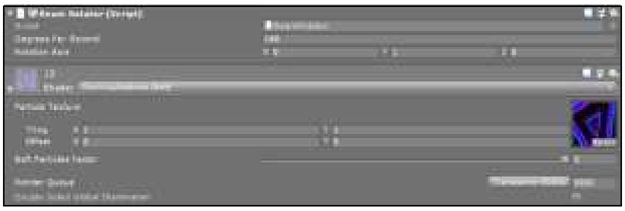

Fig. 13. Ring parameter control

The first ring developed for this purpose is shown in Figure 12 and Figure 13.

The ring shown to the user rotates at the place where the controller is pointed out to. Various contrasts and rotating speed are tested; however, based on feedbacks given by the users, it can be seen that they do not feel comfortable because the ring does not seem realistic to a real world.

The third type of ring is shown in Figure 14. Similar to the second ring, users gave a similar feedback that they do not feel comfortable due to its brightness and colorful appearance. This problem may distract users' focus and attention.

Fig. 14. Third ring representation

Unfortunately, as explained above, all three ring types are not welcomed by the users. When the testing VRelax system, it is discovered that free teleportation is not suitable for relaxation because it is often found that users trapped at various virtual locations. As a result, the level of stress may increase rather than decrease. In addition, we also faced difficulty to decide the best ring set up which would satisfy most of the users, as the users commented that they get easily distracted by the colour of the ring and its brightness.

As a result, a second version of teleportation technique called fixed destination teleportation is developed.

2. Fixed destination teleportation

In this technique, users are transferred to a fixed destination point. This technique is better than free teleportation navigation because users are aware of where they are going to, based on the mini-map displayed on the HMD as shown in Figure 18. A mini map is a view displaying all fixed location for the users to teleport. When the mini map is displayed, the user can view the teleport locations in an orderly sequence. The mini map will also help the users to feel more aware of his or her next destination point to increase the realism instead of teleporting him without awareness. Before teleporting instantly, the effect of fade in and fade out is used to imitate a blink of an eye, which creates a more realistic experience when teleporting. Adrian (2019) suggested that a proper orientation with fading effect may reduce neural conflict of motion sickness. In his experiment with 13 subjects using VR for testing different locomotion techniques of teleport, a fixed teleport destination has the least motion sickness. He further stated that point and teleport caused nausea due to disorientation. The same finding is also mentioned in [9] [10] [11] [15]. Hence, the finding from this development agrees that neural conflict of motion sickness can be reduced with a proper fade in and fade out technique to a fix destination. In addition, fixed destination teleportation prevents users from getting stuck at a certain area in the virtual environment. This technique allows the user to move in the sequenced location with ease. With many issues regarding the ring as observed in the first version of this technique, the ring was removed entirely. This navigation technique which consists of mini-map, fixed teleportation, and fading effect eventually reduces motion sickness while navigating in a virtual environment. The example of the mini-map is as shown in Figure 15. In this mini-map the fixed locations are shown in numbers that represents the sequence of movement.

Fig. 15. Mini-map displayed in the teleportation HMD

In general, the following figure shows the teleportation technique being used during the VR stress therapy. As shown in Figure 16. This navigation technique takes into consideration of all the issues highlighted by previous researchers, which is the novelty of this development process.

Fig. 16. An effective navigation technique for teleportation used for VR-based stress therapy

III. CONCLUSION

From this paper, it can be concluded that a proper integration of a locomotion technique is important to provide a realistic and immersive experience while navigating in a 3D environment. From this research, we proposed fixed teleportation using fading effect and mini map combination as the most suitable navigation technique for VR based stress therapy. This finding also supports Costas Boletsis ideas where each locomotion techniques may fit different VR application accordingly. We feel that the lessons learned throughout the development as presented in this paper may aid others in selecting a proper navigation technique particularly in the area of VR relaxation therapy.

ACKNOWLEDGMENT

This study was funded by Tenaga Nasional Berhad Seed Fund (U-TE-RD-18-03) in collaboration with TNB Counselling Unit. We would like to thank UNITEN R&D Sdn. Bhd. for fund management.

REFERENCES

[1] Al Zayer, M., MacNeilage, P., & Folmer, E. Virtual Locomotion: a Survey. IEEE transactions on visualization and computer graphics, 2018.

[2] Boletsis, C., Cedergren, J. E. "VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques. Advances in Human-Computer Interaction", 2019.

[3] Bozgeyikli, E., Raij, A., Katkoori, S., Dubey, R. Point & teleport locomotion technique for virtual reality. In Proceedings of the 2016 Annual Symposium on Computer Human Interaction in Play (pp. 205-216). ACM.P. Tay and J. Havlicek, Image Watermarking Using Wavelets, in Proceedings of the 2002 IEEE, pp. II.258 – II.261, 2016.

[4] Bozgeyikli, E., Raij, A., Katkoori, S., Dubey, R. Locomotion in virtual reality for room scale tracked areas. International Journal of Human-Computer Studies, 122, 38-49, 2019.

[5] Funk, M., Muller, F., Fendrich, M., Shene, M., Kolvenbach, M., Dobbertin, N., & Muhlhauser, M. Assessing the Accuracy of Point and Teleport Locomotion with Orientation Indication for Virtual Reality using Curved Trajectories. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. ACM.J. Eggers, J. Su and B. Girod, Robustness of a Blind Image Watermarking Scheme", Proc. IEEE Int. Conf. on Image Proc., Vancouver, 2019.

[6] Gugenheimer, J., Stemasov, E., Frommel, J., Hukzio, E. A Demonstration of ShareVR: Co-Located Experiences for Virtual Reality Between HMD and Non-HMD Users. In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces VR (pp. 755-756). IEEE. March, 2018.

[7] Huang, Z., Zhang, Y., Quigley, K. C., Sankar, R., Wormser, C., Mo, X., Yang, A. Y. Accessibility of Virtual Reality Locomotion Modalities to Adults and Minors, Robust spatial watermarking technique for colour images via direct saturation adjustment, Vision, Image and Signal Processing, IEE Proceedings, vol. 152, pp. 561-574, 2019.

[8] Hunt, X., & Potter, L. E. High computer gaming experience may cause higher virtual reality sickness. In Proceedings of the 30th Australian Conference on Computer-Human Interaction (pp. 598-601). ACM. December, 2018.

[9] Habgood, MP Jacob, David Moore, David Wilson, and Sergio Alapont. "Rapid, continuous movement between nodes as an accessible virtual reality locomotion technique." In 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), pp. 371-378. IEEE, 2018.

[10] Moghadam KR, Banigan C, Ragan ED. Scene Transitions and Teleportation in Virtual Reality and the Implications for Spatial Awareness and Sickness. IEEE transactions on visualization and computer graphics. 2018 Nov 30.

[11] Ng AK, Chan LK, Lau HY. A study of cybersickness and sensory conflict theory using a motion-coupled virtual reality system. Displays. 2019.

[12] Líndal, P. J., Johannsdottir, K. R., Kristjansson, U., Lensing, N., Stuhmeier, A., Wohlan, A., & Vilhjalmsson, H. H. Comparison of Teleportation and Fixed Track Driving in VR. In 2018 10th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games) (pp. 1-7). IEEE, September, 2018.

[13] Seo, J. H., Bruner, M., Payne, A., Gober, N., & Chakravorty, D. K. Using Virtual Reality to Enforce Principles of Cybersecurity. Journal of Computational Science, 10(1). H. Daren, L. Jifuen,H. Jiwu, and L. Hongmei, "A DWT-Based Image Watermarking Algorithm", in Proceedings of the IEEE International Conference on Multimedia and Expo, pp. 429-432, 2019.

[14] Spada, A., Cognetti, M., De Luca, A. "Locomotion and Telepresence in Virtual and Real Worlds. In Human Friendly Robotics" (pp. 85-98). Springer, Cham, 2019.

[15] Torok A, Kobor A, Honbolygo F, Baker T. A novel virtual plus-maze for studying electrophysiological correlates of spatial reorientation. Neuroscience letters. 2019 Feb 16;694:220-4.

[16] Vince, J. Introduction to virtual reality. Springer Science and Business Media 2014.

[17] Zainudin, A. R. R., Yusof, A. M., Rusli, M. E., Yusof, M. Z. M., & Mahalil, I. Implementing immersive virtual reality: Lessons learned and experience using open source game engine. In 2014 IEEE Conference on Open Systems (ICOS) (pp. 105-111). IEEE.C.S. Lu, H.Y.M Liao, "Multipurpose watermarking for image authentication and protection," IEEE Transaction on Image Processing, vol. 10, pp. 1579-1592, Oct. 2014.

[18] Zhang, C., & Chen, B. Enhancing Learning and Teaching for Architectural Engineering Students Using Virtual Building Design and Construction. Higher Education Studies, 9(2), 45-56.R. Mehul, "Discrete Wavelet Transform Based Multiple Watermarking Scheme", in Proceedings of the 2003 IEEE TENCON, pp. 935-938, 2019.