Navigation and Speed Regulation Aimed at Travel through Immersive Virtual Environments: A Review

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***Abstract* —The recent technical and interaction breakthroughs within the virtual reality (VR) sector have marked a new age. This has also led to a huge advancement of technology in the arena of Virtual environment locomotion. Fixed movement speeds are impractical while virtually exploring huge areas because of the long distances involved and various details. However, in order for clients to manually modify the journey speed, they will be required to regulate different factors that can make them awkward and will take intellectual work on their behalf. Therefore, there is a need for more investigative and comparative research on present VR navigation techniques. This is necessary so that the distinctive interaction aspects of these methods can be documented and used to lead the process of designing new techniques. In this article, a comprehensive, objective evaluation study of existing and widespread VR navigation and automatic speedadjustment techniques is presented, with the goal of assessing the user experience that each methodology provides.**

Keywords— Augmented Reality, Virtual Reality, Multimedia information, Computer Graphics, Human-Computer Interaction.

I. Introduction

The most prevalent type of interactive activity carried out in three-dimensional virtual worlds is navigation. Navigation refers to the movement both inside and outside of an environment (VEs). However, users frequently find that it is a difficult task to do because it demands not just spatial orientation but also interaction in order to successfully navigate [1]. Wayfinding and traveling are the two primary activities involved in 3D navigation from a purely technical standpoint. After the basic head movement, traveling is most likely the most prevalent type of interaction in virtual environment (VE) apps. When using the majority of VE apps, the customer needs to be capable of navigating the ecosystem in an efficient manner in order to acquire various perspectives of action and develop a sense of presence within the 3D world. In light of this, it is absolutely necessary for travel methods to be well-designed and thoroughly comprehended in order for VE applications to be successful. In the majority of situations, moving is not an ending in and of itself; instead, this is merely employed to transfer the customer into a place in which he/she is able to execute several additional works that are further significant. Due to this, the transport method Ought to be user-friendly, straightforward to understand, and unobtrusive. Since it is not always evident whether or not a certain method satisfies these criteria, formal evaluation and analysis are quite crucial [2].

Efficient and natural navigation in the design of the built environment remains a difficult challenge.Because most VEs cover more ground than could be taken inas a given vantage point, consumers need to have the ability to freely move about the environment at high speeds. This will allow them to obtain numerous perspectives on the actiontaking place. In point of fact, the utility of a 3D world is clearly proportional with regard to the degree that the user iscapable of navigating it and engaging with many elements inside it. A lot of existing user interfaces completely overlooks the possibility of adjusting the travel velocity. They just fix itto a value that seems like an acceptable constant velocity instead. As long as there is not a huge amount of variation in the size and complexity of the surroundings, this works quitewell. This is because a constant velocity is always proportional to the distance.

The user has a variety of options available to them for regulating the speed of the game. The position of the head is taken into consideration to express the navigation direction in gaze-directed steering, for example. This sort of steering is also known as head-directed speed control since the location of the head (in relation to the body) can be utilized to specify speed. Lean-based velocity [3][4] is the term for this type of velocity. An approach that determines tempo based on the position of the hand with respect to the body [5] is another one that works well with pointing. The usage of two buttons is an example of a discrete approach for controlling speed: one button increases the speed by a given amount, while the other button decreases the pace. These entire manual controls have the benefit of giving the customer full power over the movement rate. Enabling the user to regulate speed directly has one significant weakness: it complicates the development of the interface because the user must continuously observe and make adjustments to the speed as per the existing surroundings [6] have the benefit of giving the customer full power over the movement rate. Enabling the user to regulate speed directly has one significant weakness:it complicates the developmentof the interface because the user must continuously observe and make adjustments to the speed as per the existing surroundings [6].

In this paper, the five sections are organized in such a way that each section contains details about the related topic. Section II features a literature review of the related state-of-the-art works and techniques. Section III describes the discussions and limitations of these presented methods. Then comes the conclusion and future aspects of these works, which are presented in section IV. References are provided in the last section.

II. RELATED WORKS

A number of researchers have discovered travel and navigation issues in the setting of immersive virtual environments (IVEs) along with 3D computer interface activities. It is essential, in order to learn how to design effective VE travel interfaces (Figure 1), to do research on and get a knowledge of human motion control andnavigation, this remark was made in consideration of the fact that researching and understanding physical direction and control system is vital. Despite the fact that this work does not specifically address the rational problems that underpin virtual world navigation, this topic was the focus of various research and debates [7][8]. Here we compared somerelated work in Table 1.

TABLE 1: Comparative Analysis between Multiple Parameters

Ref.	Year	Parameters	Value
[7]	1993	Gaze-directed	12.15
[8]	1995	Pointing	9.75
[9]	1990	BS Distance	200m
[10]	2008	Uncovered Area	10 x 10 m^2
[11]	2015	Number of Node	2
[12]	2016	Speed	Appropriate Velocity
[13]	2019	Input Conditions	Continuous

In settings that are shown in three dimensions, several different models of perspective movement and control have been offered. Ware et al. detect three separate metaphors which are flying, having an eyeball in your hand,

and having a scene in your hand. A method of picking navigation targets known as "ray casting" [9] is the subject

of a fourth model that has been developed. Others use a depiction of the "World in Miniature" as a means of movement or navigation in immersive virtual worlds.

A. Steering Method

Steering strategies are frequently utilized when going through Immersive Virtual Environments (IVEs) for the purpose of travel. They differ from target-based strategies. They do not require the user to explicitly specify the location of the target. These strategies are typically simple to comprehend, and they give the user a high level of control [10].

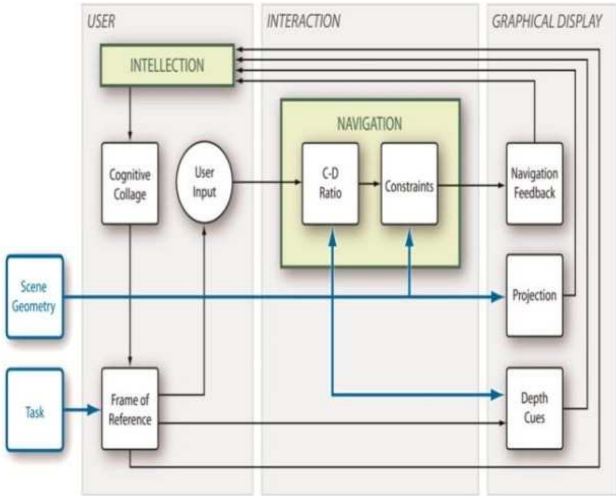

Fig. 1. Various factors for IVEs

When traversing large settings, keeping a consistent pace might take up a substantial amount of time, especially if there are many obstacles in the way. In addition, if the travel accuracy in some areas is something that needs to be kept, a straightforward increase in the trip speed across the board is often not a feasible strategy. An additional option is to utilize interfaces that provide for changeable and interactive modification of the trip speed. On the other hand, they need the user to keep control over an extra parameter even while they are moving, which can be a nuisance and may increase the mental strain. This can be an unwanted outcome given that travel is typically simply a supporting duty [11].

VIEWPOINT MOVEMENT TECHNIQUE:

As a direct result of this, there are now methods available that can automatically adjust the travel speed in accordance with the environment of the user. Mackinlay and colleagues [12] suggested that the speed of a voyage needs to be altered in accordance with the amount of time remaining before arriving at a predefined destination. One such strategy is known as the point of interest movement (POI for short). The best way to solve this issue is for the user to pick a point of interest (POI) on the surface of the item someplace. After that, the user initiates the computation of the subsequent function by clicking a button on the mouse, and the calculation begins by applying the distance to this particular point of interest:

$$f(t) = d - de^{-kt} \tag{1}$$

Here d represents the distance towards the POI, and k stands for the proportionality constant that governs how the distance shifts over each animation cycle. The moment in time at which the movement of the point of interest cuts the required region, that point in time indicates that the movement is quick. Ware and Fleet presented a strategy that models the depth buffer to predict the distances toward the system in the range of vision [13]. This idea was centered around the fact that, overall, users desire to go quicker while they are distant from scene objects [14].

On the basis of this information, they modified the travel speed in a number of different ways, finding that they had the most success whenever the mobility speed was computed based on the distance to the object that was the nearest to them.

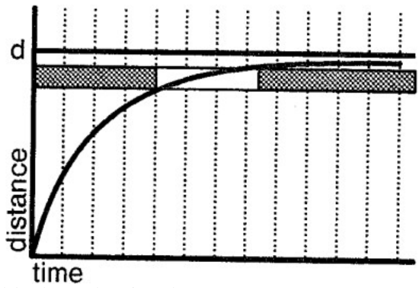

Fig. 2. Logarithmic motion function

B. Multiscale method

In other instances, such as geography and other Virtual Environments, there are also problems with the size fluctuation. The presence of such scale variations makes navigating these ecosystems more challenging than it would

Otherwise be. It is important to make continuous, non-intuitive alterations in either the scale or the velocity in order

to produce pleasant and steady navigation. These modifications are dependent on whether or not the things being observed are physically closer to the viewer. You may find instances of ecosystems that suit this definition in a wide variety of different disciplines of specialty, including medicine [15], geography, and engineering. For some applications, the use of multi-scale techniques can be beneficial because it makes it easier to manipulate items and navigate all over the simulated model, it helps to controlthe constraints of the physical environment [16], and it supports collaborative efforts in virtual environments. Additionally, for some applications, the use of multi-scale techniques can be beneficial because it makes it easier to manipulate objects and navigate throughout the virtual model. Utilizing strategies that operate on several scales is the key to successfully achieving each of these objectives. All ofthese goals can be accomplished by using multi-scale techniques. In situations like these, employing these methodsmight be beneficial to certain application areas.

a. The act of obtaining and registering information that is crucial to automatically estimate the steering speed of aspecific scene.
b. Answering the issue of which speed is suitable fornavigation based on the information that has been supplied and registered in the preceding.

C. Level of Scale Method

Applying Level of Scale (LoS) solutions is one way of approaching navigational challenges. The user is able to manually regulate their user representations and VE size in this family of techniques [17], make use of visual landmarks, or end up making use of hierarchies to stack each part at the same scale level and navigate systematically through each one [18].

USING A HIERARCHICAL SYSTEM:

This information may be found in Kopper et al. It does this by employing the idea of visual markers as it travels through several levels of the hierarchical model of the humanbody.

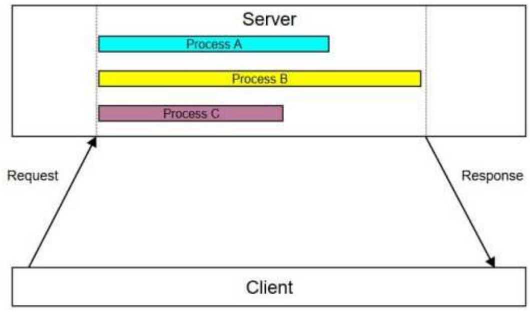

Fig. 3: The Round-Trip Path in RMNS architecture.

This method considers the dynamic rescaling of the user to fit inside the Level of Scale. Thus making it the total working environment.

$$Scale\ Factor = \left(\frac{Volume_{NewLoS}}{Volume_{LastLoS}} \right)^{\frac{1}{3}} \quad (2)$$

As the proportion amid the volume is utilized for determining the scale factor in this technique, this is due to the fact that volume describes the size of LoS, which is a three-dimensional environment. They also demonstrated that automated scaling is more effective than labor-intensive scaling while travelling past visible landmarks.

USING A TREE-LIKE FRAMEWORK

In contrast, Bacim*et al.* uses a tree-like framework to steer through several scale stages of the humanoid body. It is vital for the user to have the ability to freely explore the environment in various contexts where the environment reflects geographical data, such as oil fields and maps, in order to obtain a deeper comprehension of the spatial data [20]. This is because the environment reflects the spatial data. But moving around freely in a three-dimensional virtual reality can be challenging, regardless of how well-versed the individual is [21], and it may be impossible for beginners, especially when working with vast multiscale landscapes. In situations like this, the software needs to be able to calculate the optimal speed that according to the scale level that is currently used by the user.

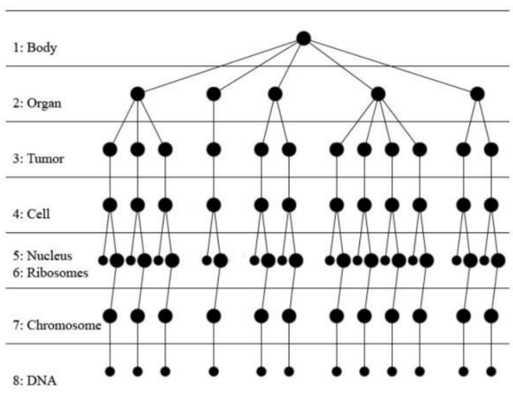

Fig. 4: The tree structure in Multiscale VR Wayfinding by Bacim*et al.*

D.Automatic Speed Adjustment Method

Automatic speed adjustment techniques, also known as ASATs [22] are yet another approach to solving thesekinds of problems in navigation. These techniques take the position of the nearest geometry as an input to heuristics, which then determine the speed of navigation that is most effective at any given time. Because the user has to actively assess the surrounding scene in order to acquire a better grasp of the space around them, this kind of strategy is appropriate for virtual environments (VEs) that are founded on geographic information.

CUBEMAP TECHNIQUE:

The Cubemap [23] is a well-known example of ASAT method. In this method, the speed selection process involves producing a depth CubeMap from the camera point, which takes into account the proximity to the environment in all directions. It executes a total of six rendering passes, each of which is performed in a distinct direction, to compute the distance between the camera and the environment. The goal is to cover the entire scene and find the optimal speed of navigation. The technique is described in Figure 5 and Figure 6 below.

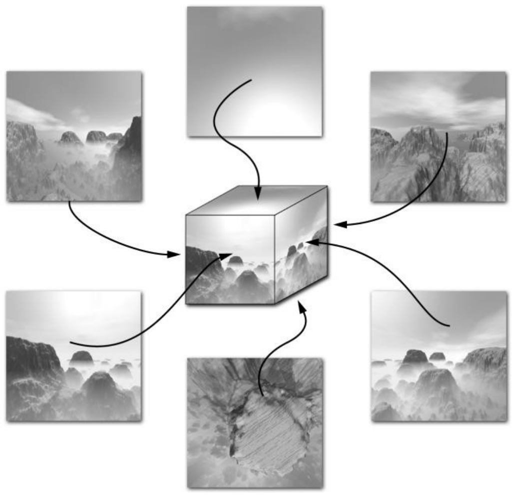

Fig. 5: Texture image for a Cube map

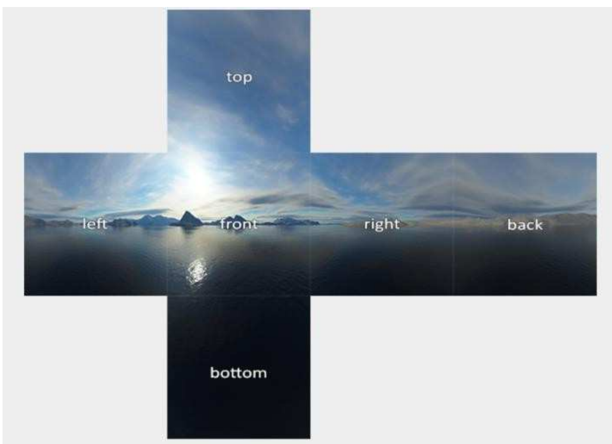

Fig. 6: Simulation of a landscape using CubeMap by Folding 6 sides of a textured cube

Eachcomponent of the structure reflects a context of items that areworking at the same scale level, and several sizes at which these ecosystems function give aspects that may be characterized by a hierarchical structure.
Hierarchical structures can be characterized by the following: After some time had elapsed, this approach was enhanced by taking into account, in addition, the distance towards the scene in the direction of motion, with the distance being aggregated over time. This improvement was made after some time had passed. After a period of time had elapsed, this newly added functionality was finally put into effect.

VIEWPOINT QUALITY TECHNIQUE:

Techniques that are dependent on the closeness to the surrounding geometry might be tricky in sections that have substantial interior regions. This is because the user is often in close contact with geometry (such as walls and floors) in these portions of the scene [24]. Therefore, as an alternative to using this criterion, the quality of the viewpoint has been suggested as a set of factors for determining how quickly the journey should be taken.
A scalar number that specifies how informative a particular place in a virtual world can be is referred to as the perspective quality. It is considered to be the viewpoint characteristic that pertains to that position. It is possible to compute it in a variety of various ways using Viewpoint Quality Estimation (VQE) methodologies (like object uniqueness, viewpoint entropy [25], etc.), and these ways vary depending on which components of the scene visible from a specific vantage point. The following figures (Figure 7 and figure 8) represent the outcome of two different techniques.
The perspective quality is lower in most of these measurements for positions in vacant halls, as there is not much information that can be acquired about the scene from there. On the other hand, viewpoint quality is higher in rooms that are furnished or adjacent to detailed items. Papoi *et al.*(2016) have proposed an innovative and effective method for automatically adjusting the speed of a user's activity.

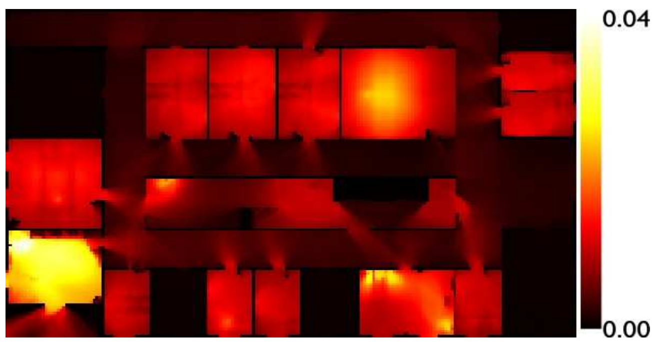

Fig. 7: Viewpoint quality q(p) for a horizontal slice of the scene (1.60 m above the ground)

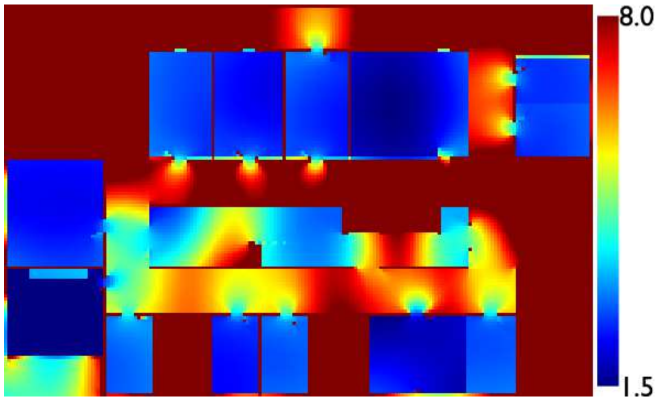

Fig. 8: Travel speeds v(p) (in m/s) resulting from a novel viewpoint quality approach.

This innovative approach takes into consideration the geometry of not just the environment all around the user but also the space that is immediately in front of them. This method can be significantly sped up in comparison to those reliant on the CPU if multi-pass shaders are used.

III. DISCUSSION AND LIMITATIONS

During the process of obtaining information on cutting-edge procedures, a number of interesting facts concerning these treatments surfaced. In other words, inexperienced users will replicate stare-controlled navigation with pointing (as in the relative motion experimentation) unless there are enormous benefits for doing something else other than imitating stare-directed steering.

In the experiment that Bowman and his colleagues conducted, this phenomenon was observed once more. It was discovered that the torso-directed steering strategy had the same quality as the other approaches. It is a distinct possibility that this was one of the contributing factors that led to the finding that there were not any significant differences between these procedures [27]. It is hypothesized that users who have more expertise with the approaches would be able to use them in a manner that is more beneficial to them. For example, when moving ahead using the pointing or torso-directed steering techniques, glance to the side as the person moves forward). It could be interesting to include the level of experience of the users as another independent variable if there were a significant number of experienced users of the methodologies being tested [28].

Despite the fact that the user study demonstrated the efficiency and applicability of the method, there are still certain limits that may be seen in the case of Freitag *et al.*'s viewpoint quality method for speed adjustments. First, The method was able to get success in a single setting [29]. Thus, the outcomes may not be applicable to other kinds of contexts [30]. The success of the strategy is dependent on the VQE algorithm that is utilized to generate meaningful perspective quality values [31]. This algorithm needs to be tested on additionalscenes in the near future.

IV. CONCLUSION

In this paper, we have described various approaches and frameworks for travel navigation and speed adjustments in the case of immersive virtual environments. These methods meet a need for a context in which an organized study of VE interaction and related properties may be carried out, and they do so by providing that environment. Because it takes into account a wide variety of elements that can have an effect on performance, our methodology ought to generate results that can be reused and generalized.

Experiments to properly evaluate travel procedures are challenging to both implement and carry out due to the nature of the task. In terms of making navigation easier, researchers frequently propose methods that examine the environment and figure out the best possible speed. So, it is necessary to develop bespoke software, which includes not only the techniques themselves but also the environments that will be utilized, data collection algorithms, and code for managing experimental sessions. As a result, we are in the process of developing a software system that, in accordance with the architecture of our assessment framework, makes it possible to conduct formal experiments involving a huge number of independent and dependent variables.

The experiments invariably result in the generation of a greater number of intriguing questions than they do in the provision of answers. Not only should these but in the future, the environment scene be broken into distinct sub-scenes.

In addition, the concept of viewpoint quality does not account for all aspects of travel, particularly certain facets of the experience. For instance, even though the quality is just slightly better in the corners of the corridors, it may be beneficial for users to slow down in certain areas. In addition, the majority of users presumably desire to move at a slower pace when they are in vacant but confined locations or when they are getting close to walls. This can be made far better by combining different methods with an approach that is dependent on the distance to the environment, which would then only be applicable for situations involving near distances. In conclusion, it is important to investigate whether or not automatic speed adjustment, in general, has an impact on one's ability to perceive their surroundings.

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