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Combined Navigation Aids In Single User Virtual Environments: A Performance Study

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Abstract

Single User Virtual Environments (SUVEs) employ a range of interaction techniques tailored to specific tasks and applications. The variability in user needs and system requirements has prevented the emergence of a universally effective solution. Effective work in SUVEs often relies on communication channels that enable users to share task goals, manage task decomposition, and monitor progress. In this paper, we evaluate the impact of six combinations of navigation aids: 3DML + Arrows-Casting, 3DML + Audio, Audio + Arrows-Casting, Textual + Arrows-Casting, Audio + textual and 3DML + Textual. The assembly task in SUVE is guided by combined navigation aids and using the shortest path selection algorithm (Dijkstra's). Experiments were carried out on university students to evaluate their effectiveness on task performance in assembly activities of using six navigational aids. Our experiment involved 20 individuals. Findings show that the combination of audio + arrows-casting resulted in the most efficient task completion, while 3DML and textual aids support led to slower navigation performance. This

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study contributes to understanding the effectiveness of different navigation aids for enhanced user performance in SUVE in assembly tasks accomplishment.

Keywords: 3D virtual environments (VEs), combined navigational aids, Virtual reality (VR), Single User virtual environments (SUVEs), Navigational aids, Three dimensional map with liner (3DML) ·

Introduction

Virtual reality (VR) is an immersive technology that enables users to experience and interact with simulated environments using a range of sensory input devices such as head-mounted displays and haptic feedback systems (LaViola Jr et al., 2017). In recent years, VR has been used in a variety of fields, including education, therapy, architecture, and entertainment, due to its ability to create highly realistic and engaging experiences (Abdelhameed, 2013; Merchant et al., 2014; Riva & Gamberini, 2000). In virtual settings, modalities encompass the diverse sensory inputs provided to users for engaging with the virtual realm. These modalities encompass visual, auditory, haptic, and olfactory stimuli etc. (Witmer & Singer, 1998). By combining these modalities, virtual environments can create highly immersive and engaging experiences that enable users to feel like they are truly present in the simulated world. In order to enhance user performance within virtual environments, different navigation tools such as maps, vision, sound, arrows, lighting, and compasses have been used to guide users through the environment (Chen & Stanney, 1999; Darken & Peterson, 2002).

Navigation relying on maps has been a popular method utilized in virtual environments to guide users through the environment (Tversky et al., 2002). It integrates a graphical map with a text-based interface to assist users in navigating the environment without necessitating the construction of a cognitive representation of its spatial layout. Maps can aid in search tasks within virtual environments by furnishing users with survey knowledge that may not be acquired solely through navigation within the environment (Savino et al., 2019). A 3D map with Line provides guide from the source to the destination to help users navigate easily in virtual environment (Khalid et al., 2019; Khalid et al., 2021). Visual guidance methods, such as arrows-casting, have been used to help users navigate and orient themselves in virtual environments, leading to improved performance and reduced disorientation.

Spectrum of Engineering Sciences
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Online ISSN
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Print ISSN
3007-312X

For example, Kray et al. utilized an arrow-based guidance system to direct participants to their target locations within a virtual environment, and found that it improved navigation performance compared to a non-guided condition (Moffat & Resnick, 2002). Audio plays a crucial role in creating a sense of presence and immersion in virtual environments by providing users with spatial and contextual information (Slater, 2009). In a study exploring different modes of interaction, including audio, video, handwritten, typed, and in-person interactions and communication, it was found that people tend to speak more than they write, and audio was the most effective means of communication for completing tasks efficiently (Friesen & Kuskis, 2013).

(Sampaio et al., 2005) created a visual representation simulating the construction of a wall that utilized textual aids to provide users with detailed instructions and information. In 2014, (Rehman et al., 2014) constructed a virtual electrical transformer designed for step-by-step assembly activities. They employed semantic assistance, such as written content and sound, to aid trainees in assembling transformer parts. (Ullah et al., 2016) developed the Multimodal Virtual Chemistry Laboratory (MMVCL) which incorporates procedural guidance for simulating chemistry experiments. The procedural guidance in MMVCL includes textual information accompanied by arrows illustrating the process of a task. Users adhere to these instructions to complete experimental tasks correctly, thereby enhancing their learning process, constructing a comprehensive mental framework. (Montuwy et al., 2019) conducted a study to assist elderly pedestrians in a simulated urban environment by providing combined navigation guidance directions. The aim of the study was to assess the efficiency and effectiveness of three different sets of navigational guidance instructions: visual and auditory support, visual and haptic assistance, and auditory and haptic guidance. Assessment results revealed that instructions combining visual and auditory assistance yielded enhanced performance and user experience when compared to haptic guidance.

In the course of several years, the probability of increasing a number of applications and students' achievement in using SUVE applications became critical when such systems are used in training, simulation and entertainment. Overall performance in SUVE can be improved by proper configuration of VE, application improvement and caching and buffering, network improvement

Spectrum of Engineering Sciences
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Print ISSN
3007-312X

and content improvement, timely maintenance of the system, single user's virtual environment improvement, consulting experts and suitable modalities. In prior research, the influence of aids on the performance of the user in virtual environment has been investigated. The studies of the application of combined navigational aids such as Arrows-Casting + 3DML, Arrows- Casting + Audio, Arrows-Casting + Textual, Audio + Textual, 3DML + Audio and Audio + Textual in CVE were done to determine user performance in CVEs. In this study six navigational aids 3DML + Arrows-Casting, 3DML + Audio, Audio + Arrows-Casting, Textual + Arrows-Casting, Audio + Textual and 3DML + Textual are used to examine the effect on user performance in SUVE. It is therefore important to evaluate the effects of these combined navigation aids on user performance in SUVE to enable enhance the efficiency and user experience in SUVE.

The study is generic and can be used for others SUVEs with minor modification in the basic protocol. The important domain applications are assembly task in VEs (virtual machine assembly), interactive learning (virtual lab experiments), virtual users' assistance (virtual buildings) and entertainment (games) etc. The essence of this work is to analyze the following two hypotheses:

H1: The choice of interaction combined aids affects user performance in SUVEs.

H2: Which one combination of virtual aids (3DML + Arrows-casting, 3DML + Audio, Audio + Arrows-casting, textual + Arrows-casting, Audio + Textual and 3DML + Textual) for navigation enhances user performance in SUVEs?

The structure of the paper is as follows: Section 2 presents the background study. Sections 3 and 4 describe the methods, results, and discussions, focusing on the performance and realism of various combined virtual navigation aids in Collaborative Virtual Environments (CVEs), including 3DML + Audio, 3DML + textual, 3DML + arrows-casting, arrows-casting + Audio, Arrows-casting + textual, and audio + textual. Finally, in section 5 of the study conclusion is reported.

Background Study

In navigation in the user perspective, the body is moved towards a particular place in virtual world. Exploring the VE and finding way in VE are the two main types of navigation. VEs are tougher to explore than physical worlds. For

Spectrum of Engineering Sciences
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Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

example, to get from one place to another physical world, then you are supposed to use doors and gates to accessing another room. A "neighbor" within this space is accessed in terms of distance response. But in a VE, such a restriction is not present. The users are able to navigate around by teleporting to any point of interest. For instance, user can choose a particular place for himself, pointing at the map in the mini-world and move there right away. Moreover, in the physical world, the peripheral information affords references which helps to minimize the Cognitive Load. Specified and limited, the user has few clues as to how he or she is to begin to approach and make sense of the virtual world. Thus, way finding may be defined as the act of using ones spatial ability coupled with one's navigational sense of an environment in order to arrive at a certain place, becomes more challenging in a VE during movement (Aukstakalnis, 1992).

Due to more diverse inputs from multiple modalities, users may engage and travel inside SUVE. Such methods can communicate tactile signals, auditory, visual, smell and taste etc.. Researchers can get some data to help decide what practices are acceptable to enhance the user performance and give more attractive feelings of immersion in a SUVE by splitting a lot of different other modalities (Bertol, 1996). The following are several aids at SUVEs; some of them are discussed as follows:

Audio Modality

Audio aids have shown that speech is better than text-chat or screen-based communication for task completion and user performance. People are talkers more than text writes, thus, if instead of being written to, you are voice commanded; you may perform well. Besides, the value of such information is still remained, notably in terms of the virtual platform as well as the social and teleconference meeting (Anderson, 2022). Superimposing 3D audio signals that correspond with the user's perceived virtual position, as identified by tracking devices, improves the users feeling of being there and overall presence (Bhowmik, 2024). Improving auditory representation may involve getting nonverbal encodings of language through gesture, facial expressions or other actions (Zhang et al., 2022). Also, there are investigations into new ways of using auditory systems, including AV glasses or tablets to relieve scared pediatric kids during treatments. In addition, Virtual is a study tool comprising of audio/tactile signals in virtual reality ambiance for assisting and

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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Print ISSN
3007-312X

enhancing indoor mobility for the visually impaired (Patel et al., 2024). Single-User virtual environments are those where the particular user interacts with the virtual environment independently of other users. The use of audio modality for presentation and as a pointer in the virtual environment is mean to help and enhance the performance of the user.

Textual Modality

The awareness techniques which use text based messages come under the genre of the visual guidance. To move through VEs, users are directed with text. The written boxes in the form of text consist of 23 steps were given in the VE to assist the mason during construction process of the wall (Craig et al., 2009). Students in V-Lab perform chemistry lab experiments with the help of text-based 2D collaboration in which equipment and chemicals for lessons and experiments as well as making requests for explanation and questions were displayed to him in the form of text (Rahmahati, 2015). To improve the learning level of employee in VR and AR training system for assembly and maintenance type activities the textual aids were use.

Comparing the results of textual annotations in virtual reality environments with the rewards concerning various learning results and the necessary cognitive load may enhance learning pursuant to the multimedia design principles. Textual modalities can give the user written string, name or text prompts in order to facilitate direction finding, comprehension and interaction with the virtual environment (Ward et al., 2011).

Arrows Modality

Directional arrows in SUVE help users' complete tasks by guiding them down pathways. Users' should carefully arrange arrows for effective direction because too many could disrupt immersion (Denis, 2017). These arrows, which are just temporary, make it easier for users to move around and examine stuff. By allowing installation at various altitudes and orientations, dedicated 3D arrows enhance the user experience and make it easier to explore environments with several floors. To enhance the performance of driver in a VE arrow-based navigation are used. The stationary arrows based navigation was proposed by Monahan et al. on a screen to show mechanical direction (Monahan et al., 2008; Newman et al., 2007). To explore pathways, Raees and associates developed a three-dimensional virtual environment (VE). In their technique, they employed arrow-based guidance (Raees et al., 2019).

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Using arrows as visual signals can help users navigate the virtual environment by showing themwhich way to go.Screen arrows that point to particular places, routes, or interesting things can be seen. They offer an easy to understand graphic depiction of the desired navigation route. Arrows can help users effectively reach their intended destinations, improve us er orientation, and lessen the ambiguity.

Haptic Modality

In a tangible sense, virtual interactions could enhance spatial awareness and immersion. It can be utilized for movement as well as transportation, such as manipulation, including use force feedback to interact with things, and vibration to change direction. Restrictions: requires specialized, expensive, and less accessible equipment, including haptic gloves (Ullah et al., 2009; Wang et al., 2024). Certain virtual environments or interactions might not be compatible with it. Examples of Navigational Aids: It is possible to move objects and change the direction of forces by using vibrations.

Visual and Haptic Modalities

When it comes to single-user virtual worlds, the combination of haptic and visual input greatly increases user immersion and task performance. Stimuli are provided by visual input, and the game's realism is increased by allowing players to physically interact with virtual objects through haptic feedback. Additionally, studies show that this will greatly enhance motor coordination and spatial orientation in virtual activities. In contrast to when just visual feedback was provided, (Patil et al., 2018) discovered that when ASU was used to provide both visual and haptic input in his study, participants were able to rapidly distinguish between the surface texture and form of virtual objects.

Visual and Auditory Modalities

A key factor in improving virtual reality is the use of both visual and auditory elements. The user's realism and position awareness within the VE are enhanced by this combination. In ways that graphics cannot, sound can convey crucial information or suggest the best viewing posture. (Calvert & Hume, 2023)., for instance, found a strong response to multimedia in which music increased users' spatial presence and vision in virtual settings, even in the face of competing inputs.

Spectrum of Engineering Sciences
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Print ISSN
3007-312X

Visual, Auditory, and Haptic Modalities

The integration of visual modalities with auditory and haptic feedback offers the most extensive immersion in SUVEs. They highlighted how this multimodal strategy leverages the strengths of each modality to create a combination that boosts user interaction and immersion. Study conducted by (Gardony et al., 2020), demonstrated that users could effectively and accurately complete multiple tasks simultaneously when engaging all three modalities; touch, vision, and hearing as compared to when only one or two modalities were employed.

Visual and Olfactory Modalities

Auditory and visual cues, although not as common, can enhance a user's sense of presence and emotional reaction to a virtual reality experience. In the context of virtual reality, aromas can evoke powerful emotions and trigger memories from the past. Additionally, research conducted by (Yanagida et al., 2004) indicated that incorporating scent into virtual environments could greatly enhance the user experience, making it easier to appreciate the experience due to its increased authenticity.

Auditory and Haptic Modalities

These approaches are most effective when visual attention is limited or only briefly available in a particular task. The mixed-use bimodal strategy either offers additional or supportive information, which enhances the quality of interaction. For instance, (Brown et al., 2005) explored the simultaneous use of auditory and haptic feedback to improve users' performance in situations where it is crucial to monitor changes in the environment or receive alerts, such as in alerting systems or guidance in low-light conditions.

Therefore, based on the analysis of the literature it is clear that whilst many papers have considered the role and the influence of singles and combined aids on the user performance in Virtual Environments (VEs), there is a research gap concerning the contribution of these combined aids in SUVE to increase users performance. The combined aids Arrows-Casting + 3DML, Arrows –Casting +Audio, Arrows-Casting + Textual, Audio + Textual, 3DML + Audio, and Audio + Textual reveal the possibility of improving the user performance in CVEs. However, the applicability of these aids in SUVE has not been studied before. In this paper we will investigate how these combined aids can be incorporated effectively into SUVE for an enhanced performance

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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3007-312X

by the user in the selection of the appropriate assembly task. Consequently, the results of this study could pave way for the establishment of better and more efficient user interfaces in virtual scenarios; improving the learning and training processes.

Experimentation and Analysis

Environment

In the single user virtual environment the cuboids objects were placed in different rooms. The participant will take them to the central room. In the central room they will place all the objects in a certain order so as to create the word "UNIVERSITY". Once the word is formed the assembly process will be complete. The users of the environment conduct the experiment under the following six combined condition.

C1 = 3DML + Arrows-Casting
C2 = 3DML + Audio
C3 = Audio + Arrows-Casting
C4 = Textual + Arrows-Casting
C5 = Audio + Textual
C6 = 3DML + Textual

The process of assembly task is depicted in Figure 1.

Figure 1.Virtual Environment

The weighted graph, adjacency matrix and path matrix are useful to aid users to move around VEs to use virtual objects to spell out "UNIVERSITY". The VE is an apartment with several rooms and objects; a user's task is to find the shortest way in the apartment in order to gather the objects which form a word. Weighted Graph (Figure 2) of the VE (Figure 1) indicates the objects

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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Print ISSN
3007-312X

which have been placed in various rooms equal to circular letters and the distance or cost marked equal to number? For easy understanding the starting place is labeled as "START" and the center room is labeled as "CR" has also been incorporated in the graph. The adjacency Matrix (Table 1) of the weighted graph (Figure 2) shows the relations of the vertices of the graph and in this context, the vertices are objects and rooms in the VE. The matrix illustrates the connections between the vertices (objects) and the corresponding cost for making a connection. In this context the cost is the measure in the distance between the said objects. Table 2, the Path Matrix demonstrates the shortest conversations between different pairs of objects in the VE. This matrix can be used to determine the least distance users need to traverse so as to get all the objects in question. In this example the matrix shows that the object 'V' can be reached from the starting point 'START' on two ways. The path matrix information can be utilized by users to move within the VE and reconstruct the word "UNIVERSITY" from the objects as shown in VE (Figure 1).

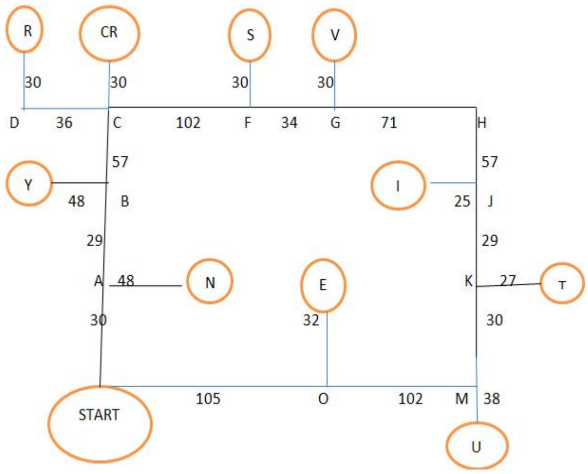

Figure 2. Weighted Graph of the VE

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SPECTRUM OF ENGINEERING SCIENCES

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Table 1: The adjacency table displays the estimated cost values for the weighted graph (Figure 2).

	START	A	N	B	Y	C	D	R	CR	F	S	G	V	H	J	I	K	T	M	U	O	E
START	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	0
A	30	0	48	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	0	48	0	0	48	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Y	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	0	0	0	57	0	0	36	0	30	102	0	0	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	36	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	102	0	0	0	0	30	34	0	0	0	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0	0	0	30	0	0	30	71	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0
V	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0	0	71	0	0	57	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0	0	0	0	57	0	25	29	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	27	30	0	0	0
T	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0
M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	38	102	0
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	0	0	0
O	105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	0	0	32
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0

Dijkstra’s algorithm helps find the shortest path for the customers in a VE to complete the assembly task. To making the word “UNIVERSITY” is an assembling task, the combined aids ArrowsCasting+3DML, Arrows-Casting+ Audio, Arrows-casting + Textual, Audio + Textual, 3DML + Audio and Audio + Textual assistant to tell the user about their progress and about the objects they have taken up. Dijkstra’s algorithm is vital to the routing to find shortest path in order to assemble the objects they need. In this way the users can optimally take their time while at the same time satisfying the assembly task, thereby reducing effort to the minimum.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Table 2 Path matrix of the weighted graph of Figure. 2 from START to V

	START	A	N	B	Y	C	D	R	CR	F	S	G	V	H	J	I	K	T	M	U	O	E
1	START	A	B	C	F	G	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	START	O	M	K	J	H	G	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Environment Structure

The VE was developed on a Laptop with Core i5 processor, 4GB memory with dedicated graphic card. Using C++ computer language and Open GL graphical library and navigation was done with keyboard commands under six combined navigational aids (C1-C6) and the Sound Tap Audio Streaming Recorder was used for audio recording. Dijkstra's method was used to identify the shortest path for the participants. Twenty volunteer students with their age ranged between 22 and 28 years. The users were first trained about the process description with a preliminary session. Time, Errors and subjective feedback matrices were used for identifying the most suitable and efficient combined navigational aids.

Tasks

The performance of the user will be assessed in SUVE by considering the conditions of C1- C6 of making the assembly of word "UNIVERSITY". A SUVE was developed as shown in figure 1 and figure 2 give its weighted graph. Dijkstra's algorithm should be used for each and every condition, with regard to the procedures or constraints that is mentioned against each condition to collect the cuboid objects from rooms and bring them to the central room of using the following procedure:

Procedures

3DML + Arrows-Casting Based Navigation

In the 3DML + Arrows-casting based navigation system (Figure 3), users are traveling through a SUVE to construct the word "UNIVERSITY". When walking in the environment they have a red path with arrows suggesting the way to the next object to be picked up. Also, a line is made which separates a 3D map; there is a blinking symbol marking the location of object. Whenever the user grabs an object for instance, "U" a new red path arrows towards the destination the central room (CR) is created and a line is drawn across the

Vol. 2 No. 4 (2024)
Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

map to direct the user to the central room. Next, after positioning the object "U" in the CR the user goes along another red path with arrows and the blinking signal on the 3D map to find the next object "N". The user accomplishes this with the help of red paths and quick blinking of the pointers on the 3D map and takes every next object to the central room putting together the word "UNIVERSITY".

Figure 3. 3DML + Arrows-Casting

3DML + Audio Based Navigation

3DML (Three Dimensional Map with Line) is employed to provide a three-dimensional interactive space for users. This makes the system to be natural, easier and more effective since it uses both the visual 3D mapping and audio based navigation. The 3D map is built using Open GL that is widely adopted 3 D graphic display technology (see Figure 4). In the context of this experiment, the map is the direct control element for a user to interact with in order to properly navigate the virtual environment. The map also shows directional indicators and played audial messages to assist the user in orientation and localization. Dijkstra's algorithm is used to determine shortest distance between user's sources to destination. This way, it makes sure that the user follows the most optimized path possible; effectively minimizing the user's mental burden and thus, the entire process flows much better. The experiment is conducted in the Usage Controlled Virtual Environment, which is abbreviated as SUVE. The assembly task where the user is needed to pick the objects with letters "U", "N", "I" etc. all alone. Nonetheless, each object is indicated on the map with a blinking effect and only the object which has to be picked up draws the user's attention. When an object is taken, the user is navigated to move the object to the central room (CR) in the environment and a line is drawn on the 3D map pointing to the central room direction where

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

the object must be moved. The text of the audio message tells the user where the next object in the sequence is located. This cycle is applied all the objects and comes to establish the word “UNIVERSITY”. The overall use of 3DML, the audio-based navigation system, and Dijkstra’s algorithm permits the enhancement of the 3DML application as improving the quality and interactivity of the user’s experience as improving the efficiency of the user’s experience within Raleigh. The user controls the movements smoothly, locates and interacts with objects, effectively managing to assemble the object by voice and visual cues.

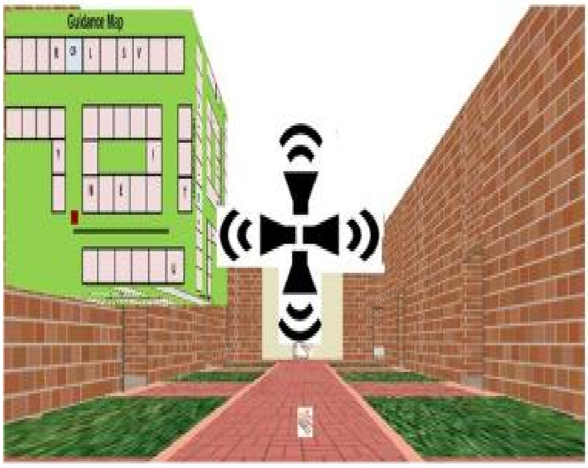

Figure 4. 3DML + Audio Based Navigation

Audio + Arrows-Casting Based Navigation

In the arrows-Casting + audio based navigation method (Figure 5), the user has to follow some steps in order to assemble the word “UNIVERSITY” while navigating in a Single User Virtual Environment called SUVE. The system assists the user in searching and engaging with the different letters that make up the word using a red line with arrows and speaks out. When the user navigates the SUVE, a red path with arrows from the user’s position to the object when it is an ‘U’ or a similar object is depicted and the user receives audial cues like “go front”, “see behind”, “see left” and “see right” to help him/her locate and pick the object. When the user manages to retrieve the letter, then the system will display information regarding the path to the next location – the Central Room (CR). As can be seen in the figure below the user will be guided by the red line with the arrows and the speaker will utter in the earpiece that the user needs to take the object to the central room. After placing the object in the CR, the user will follow paths with arrows and hear

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

the audio next letter 'N' and so on; the user will pick up next letter and bring them to the central room to assemble all the letters to from the word. In addition to the visual prompts, this type of navigation is based on an audio-tactile presentation of the users' task that involves constructing the word "UNIVERSITY" in the context of a virtual city landscape. It guides the user along a linear workflow and shows them what they are doing wrong, so it decreases cognitive load and the experience is better.

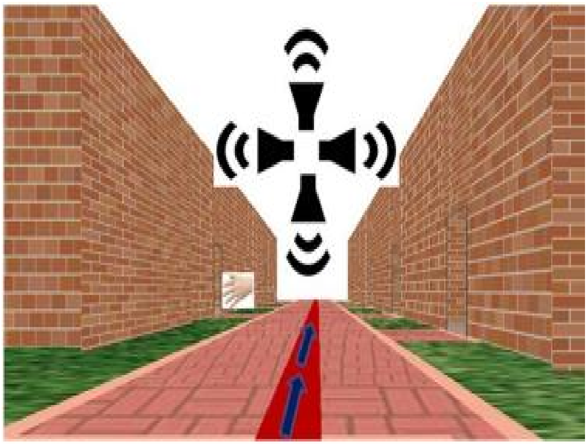

Figure 5. Audio + Arrows-casting

Textual + Arrows-Casting Based Navigation

Textual + Arrows-Casting based Navigation System presented in Fig. 6; the user has been given directions in form of red paths with arrows, and/or textual messages to guide the users in moving around the environment and also to perform certain tasks within the environment such as picking objects and arranging them in the right places. Users begin with the red path arrows pointing at object 'U' along with textual messages like "go front", "see behind", "see left", or "see right" to let them know the right direction to take. Once the user finds himself at the object "U", she/he picks it and a new red path with an arrow directs the user to the central room (CR). Now though, they also receive a message in the form of text to go to the room's center with the object. Once the first user puts object "U" in the Central Room, the system will show the red path with arrow and text message to pick up object "N". Users follow the red path with an arrow to object "N" and then are instructed to deliver it to the central Room. They persist in carrying out this operation, choosing objects and moving to the Central Room, until the formation of the "UNIVERSITY" weekday is constructed. While navigating the users are given visual prompts (red paths with arrows) and text that gives helpful descriptions on how it can

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
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be used by the users in order to accomplish their tasks and build "UNIVERSITY".

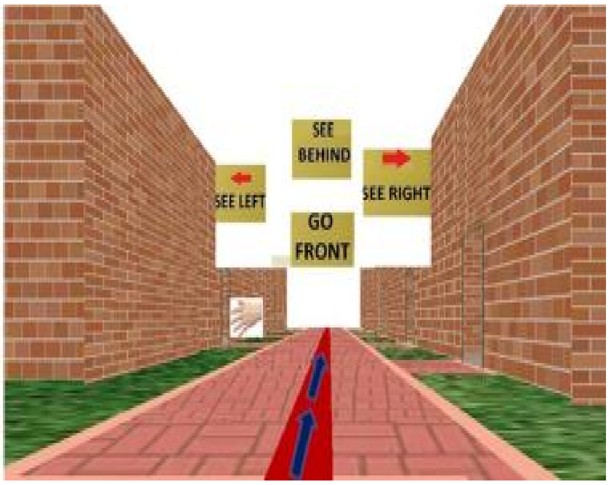

Figure 6. Textual + Arrows casting

Audio + Textual Based Navigation

In an audio + textual based navigation system (Figure 7), when the users are in an environment, and looking for an object "U" with which they intend to pick and bring to central room he is presented with different textual and audio messages which direct them to the object and how they should pick it up. For instance, textual messages like "go front", "see behind", "see left", and, "see right" are some of the messages that should be relayed to the user when searching. After the object "U" has been picked up without problem the system gives an audio + textual message to bring the object to CR. After releasing the object 'U' the audio and textual aids displayed to reach to the next object 'N' in this example until the assembly "UNIVERSITY" is completed. Due to use of both audio and textual messages, the user has full understanding of surroundings, finally making the overall navigation improve and complete the task successfully.

Spectrum of Engineering Sciences
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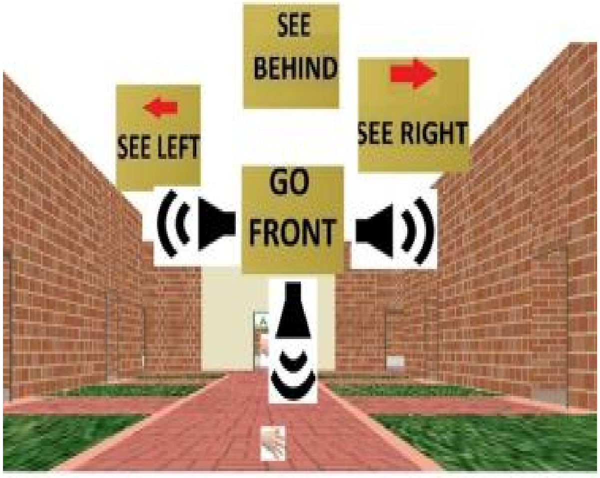

Figure 7. Audio + Textual

3DML + Textual Based Navigation

When it comes to 3DML + Textual based navigation as described in Figure 8, users are able to move through a VE dictated by the text directions and what their eyes could see were facilitated by 3DML. To navigate the users, they get textual messages for instance 'Go front', 'See behind', 'See left' and 'See right' along with visual prompts on the map that is formatted in 3D. If the user seeks to pick an item, labeled as "U" in the map, he is required to move the "U" to the Centre Room (CR) by following a straight line from the object to the room. Thus, when the user puts item "U" into the CR, they get a text message that says "Find N." Item "N" is made easily noticeable by flashing on the 3D map to get the user's attention. They create a line on the map connecting the current position of the user with item "N," which indicates the shortest distance between a user's current position and a facility "N". As soon as the positioning of object "N" is identified, the user is told to go to the subsequent item, "I", and this item starts blinking to indicate its existence. A written message is depicted to include the following instructions in order to help the user to get to item "I." This process is carried on for every item in the Single User Virtual Environment (SUVE) until the whole assembly job is through. At the end of the assembly job, the form "UNIVERSITY" appears in the virtual learning environment. In doing this, the user moves within the virtual space through both written words and graphics, the formation of which leads to a smooth, persuasive experience that enables them to build the word "UNIVERSITY."

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Figure 8. 3DML + Textual Based Navigation

Analysis and Results

Task Completion Time

To find out the most efficient aids, time is one of the important statistical analysis matric. The task completion time were calculated of performing the assembly task in SUVE to check the user's performance under six navigational techniques (C1 to C6). For each navigational aid the P values of mean time were calculated of using the statistical test of one way ANOVA as depicted in Fig. 9. On basis of the mean recorded time during conduction of the experiment in SUVE in the mentioned six navigational aids to complete the task revealed statistically significant difference i.e. (($F (5, 19) = 42.36$), $p = 0.031 (p < 0.05)$). C1 has 430.34seconds, C2 average recorded time was 480.34, C3 has 402.34 seconds average task completion time, C4 has 530.86 seconds, C5 has 585.56 seconds and C6 has 598.54 seconds. The result shows that, the combinations of Arrows-Casting with Audio (C3) enhance user performance in SUVE assembly task accomplishment as compare to the rest of navigational aids (C1, C2, C4, C5 and C6). The task completion time for the rest of navigational aids are C1, C2, C4, C5 and C6 respectively (See Figure. 9).

Vol. 2 No. 4 (2024)

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

Online ISSN 3007-3138

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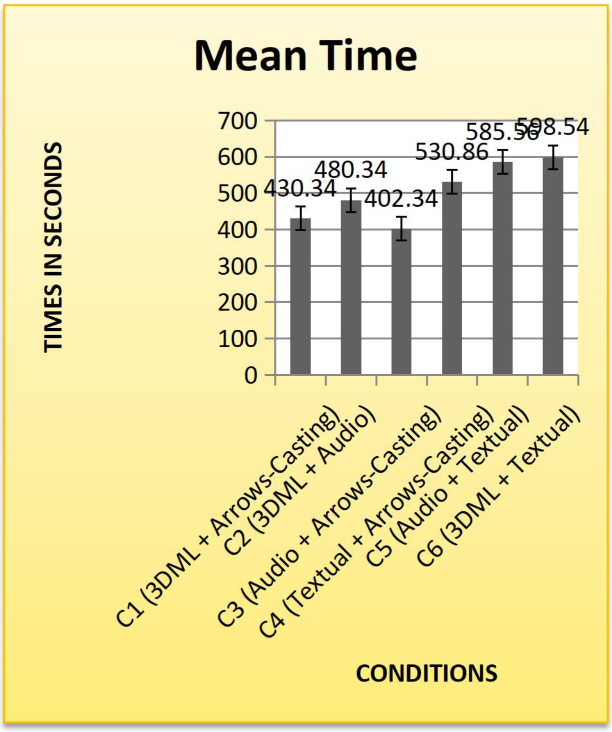

Figure 9Task Completion Mean Time

Errors Analysis

In assembly task accomplishment the users navigate in the single user virtual environment and picks of the wrong object and also to place it in wrong place other than the specified central room is considered an error. In the given scenario to check out the user performance efficiency level under the mentioned six navigational aids, the error analysis matric is used in assembly task completion. The error analysis is presented in Figure .10. The navigational aid mentioned in C1 (3DML + Arrows-Casting has 2.5, C2 (3DML +Audio) has 2.9, C1 i.e. Audio + Arrows-Casting mean error is 2.2, C4 (Textual + Arrows-Casting has 3.3, C5 (Audio + Textual has 3.65 and C6 (3DML +Textual) has 4 number of errors respectively.

The results show that C3 has fewer errors than others. In rest of conditions, the numbers of errors are less in C1, C2, C4, C5 and C6 respectively.

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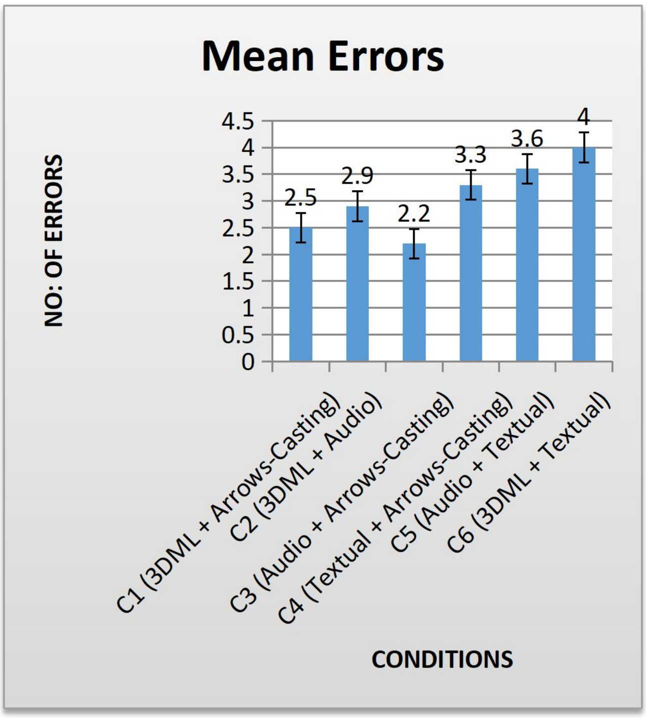

Figure 10Mean Errors

Subjective Assessments

Table 3 Subjective Questioners

The response of the participant during the experiment process (based on

No	Questions
Q1	Among the combined navigation aids, which one impacts human behaviour and productivity regarding task accomplishment?
Q2	Which among the combined navigation guides presented above do you find most relevant?
Q3	Which combined navigation guide do you find it most challenging to complete Task to its perfection?
Q4	Which mode of the navigation guide that is more useful and helpful in achieving the task? Organize on the basis of priority
Q5	The user involvement in the experimental process, which combined navigational aids to you consider?
Q6	Which combined navigational aids to you prefer in term of motivation?

Table 3 questioners) are collected and thoroughly analysed. The six combined navigational aids are given to users in the option. The user selects his/her

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
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Print ISSN
3007-312X

choice from the given options. The subjective feedback from the users in experimental process was reported in Table 4.

Table 4 Subjective Feedback

Questions	C1 (3DML + Arrows-Casting)	C2 (3DML + Audio)	C3 (Audio + Arrows-Casting)	C4 (Textual + Arrows-Casting)	C5 (Audio + Textual)	C6 (3DML + Textual)
Q1	21%	18%	25%	14%	12%	10%
Q2	21%	18%	23%	15%	13%	10%
Q3	14%	17%	12%	18%	19%	20%
Q4	20%	18%	24%	17%	14%	7%
Q5	20%	18%	22%	17%	13%	10%
Q6	20%	18%	24%	15%	14%	9%

For Q1, users preferred the Audio + arrows-casting (C3) the most (25%) compared to other conditions, suggesting a preference for this technique to support efficient and effective navigation. As far as Q2 is concerned, most users (23%) choose Audio + arrows-casting (C3) over other conditions for relevancy in the SUVE for navigation. 3DML + Textual aids (C6) in SUVE as reported 20% the task completion is more difficult as compared to other conditions. Usefulness and helpful navigation techniques among the given six conditions were Audio + Arrows-casting, 3DML + Arrows-casting, 3DML + Audio, textual + Arrows-casting, Audio + Textual and 3DML + Textual respectively. According to Q5 (the involvement of user in experimental activities) were Audio + Arrows-casting, 3DML + Arrows-casting, 3DML + Audio, Tactual + Arrows-casting, Audio + textual and 3DML + textual obtained 22%, 20%, 18%, 17%, 13% and 10% respectively. For Q6, most users (24%) preferred the Audio + Arrows-casting compared to other conditions, assuming a preference for this technique to support motivation.

Conclusion

The findings of this paper are based on an experimental research study aimed at testing a hypothesis related to the effects on user performance in SUVE with combined navigation aids. Six navigation aids were used in the

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
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Print ISSN
3007-312X

experiment interchangeably and they were paired and their performance were compared; 3DML + Arrows-casting, 3DML + Audio, Audio + Arrows-casting, textual + Arrows-casting, Audio + Textual and 3DML + Textual. In general, it can be observed that Audio + Arrows-casting, 3DML + Arrows-casting, 3DML + Audio done better than textual + Arrows-casting, Audio + Textual and 3DML + Textual aids in navigation task. It was found out that based on task completion time, number of errors and subjective evaluation, the users had better navigation in SUVE with Audio + arrows-casting than the other combination of virtual aids. i.e. H1: that the choice of 3D virtual combine navigation aids affects significantly user's performance in SUVE and H2: the Audio + arrows-casting are more effective in terms of user performance than other combined virtual navigation aids. The future work shall look at new techniques and how the use of these techniques can in SUVEs be used to improve on the performance of users. One developmental direction can be to apply all the aids dynamically in SUVEs in order to enhance the users' performance.

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