VR Voice Commands for Individuals with Motor Disabilities in an Online Learning Environment

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***Abstract*—2020 saw the start of a pandemic that forced universities to provide more online classes. With 98% of universities moving their classes online since 2020 [2]. With technology rapidly developing and evolving, having VR classrooms is something that can occur in the near future. The problem we face with online classrooms in VR would be accessibility for those with motor disabilities, specifically the upper limbs. Utilizing VR controllers may be difficult for these individuals and to supplement the problem we will be utilizing voice commands to parallel the use of controllers. The idea is not to completely replace controllers but rather it should be used in tandem with the controllers. Through analyzing our academic sources we have come to the conclusion that using an additional method of navigation for online learning platforms in VR can benefit the user. Voice commands are prevalent in day-to-day life for many individuals nowadays, using this technology for VR online classrooms could greatly increase the accessibility for those with motor disabilities.**

I. Introduction

As the online learning industry continues to grow, the development of VR is rapidly advancing as well, meaning that having interactive online classrooms in VR is something that can happen in the near future. With the number of enrollments in the hundreds of millions for online learning for just Coursera alone (see **Fig. 6**), perhaps it is safe to say that online learning will continue to grow and will likely transition in virtual reality as well. In every new platform, accessibility is a problem that needs to be addressed and in our case the goal is to address the accessibility issue for those with motor disabilities, specifically the upper limbs. The solution that we decided on is to implement voice commands in a VR classroom setting, with functionality to mute/unmute, raise/lower your hand, movement for certain situations, and finally language configuration for the voice commands. A research article based on interaction techniques for 3D layer constraint solver in a desktop-based virtual environment [4] speaks about how voice command has the highest performance and is also the most perferred by the participants in their research. While this functionality can be utilized in meets that are not necessarily educational exclusive, the main motivation in this project is for the program to be used for educational purposes. While voice commands can technically operate most of the functions of the online learning application alone, for better efficiency it should be used in tandem with the controller with the example being to have button alternatives that can be manipulated with the controller. Voice commands aren't a direct replacement but rather it makes certain tasks easier by mitigating the inaccuracy of fumbling with the controllers trying to click a button in virtual reality [3]. Another source we found conducted a research on dental implant planning procedures in VR with controllers and voice commands, it was stated that voice commands allowed the user to maintain their attention on the task without having to look at the menu which in our case would be the user interface [5]. Additional inputs to perform the same task can increase the accuracy as well as efficiency of the task which can benefit users so that their attention does not have to be diverted from trying to interact with the user interface of the application.

II. Methods

Throughout our journey in this project we used a multitude of testing methods to obtain information on how to better our application which led to a number of iterations and changes we had to implement. To begin with the methods that we used to test our application will be mentioned and later on we will go over the evolution of our application. Firstly we used a use case diagram to scope out the project (see **Fig. 2**) and decide what we wanted to do and what functionality the application should have. As the project progressed we realized that there were certain functions that we do not necessarily need and those functions were swapped out in favor of a different function that we deemed more useful, all of this is reflected in our old use case diagram (see **Fig. 1**). We used a variety of surveys like NASA TLX, System usability score, as well as the presence questionnaire which all answered important questions by the users that tested our application. We also utilized bodystorming and wizard of oz prototyping to get a better idea of how our application works and the prototyping is what we used for user testing. Body storming is more of internal testing between our group members (see **Fig. 4**) so that we can grasp what we think we need or what we think is missing, using the wizard of oz prototype we can body storm certain scenarios to get the information needed. Through wizard of oz prototyping we can perform bodystorming as well as user testing to identify the positives and negatives of our application internally (see **Fig. 3** & **Fig. 12**). We then used our wizard of oz prototype to conduct user testing which would be external and no bias as opposed to testing with our group members. The surveys consist of NASA TLX which tells us the emotions that the user may feel like frustrations for example, system usability score implies that it gauges the usability of an application, and lastly the presence questionnaire has a variety of categories that it rates the application with ranging from realism to self-evaluation of performance. All of these surveys let us know what people think we need to improve on and potentially change in our application.

III. Results

Our application has gone through numerous iterations and changes. We had to pivot our idea from targeting online classrooms in general to focusing down on virtual reality online classrooms. Bodystorming gave our group a better understanding of how the user would probably interact with our application. By creating scenarios along with our wizard of oz prototype, we're able to internally test our application which in turn helped us identify some issues. Some of these issues include: mute command allows everyone to hear you say mute so our solution then would be to have the application automatically mute over a period of time, another issue being that teleporting movement is tedious with constant inputs and inaccurate, so our solution was to allow continuous movement which can be used in conjunction with teleportation movement. After we conducted user testing and had the users complete surveys we had additional information to work with in terms of improving the functionality of our application. Firstly the NASA TLX (see **Fig. 7** & **Fig. 8**) basically helped us identify what emotions the user experienced while testing our application. Although there is some information that is unnecessary like how there is no conceivable way that our application would be physically demanding as it is only voice commands. But some useful information that is useful is that most users were not frustrated which would mean that they did not get stumped or annoyed with inaccuracy. Next the system usability score (see **Fig. 10** & **Fig. 11**) while our average is 71.5 which is above average it would mean that our application is satisfactory but with plenty of room to improve, namely our application should improve the consistency as pointed out from the survey that some people think that our application is inconsistent. Last survey we had is the presence questionnaire (see **Fig. 9**) which gauges a number of categories, some categories do not matter as much to us and are not a focus like realism. Some other categories like quality of interface which we scored a 60% on is something we know to improve on as the project progresses. We also have other feedback outside of the survey that we received verbally. Having certain spots that the user can teleport to directly is efficient i.e. the user can directly teleport to a certain desk rather than manually navigating there. We realized we had to enable/disable voice commands recognition so that the application does not have any misinputs. Having an interface with the instructions was also something we completely overlooked as all the users testing our application had no idea what the commands were. We also realized that like all the sources that we researched that removing WASD/controller movement and relying solely on voice commands was not a good idea so we kept both methods of input. Even with flying unmanned aerial vehicles a research done on voice command controls created for flying such vehicles are created for flexibility and not as a direct replacement for existing controls [1]. Overall our biggest hurdle with this project is the voice recognition. We had the application picking up noises and reacting to the noises but it could not differentiate noises and words.

IV. Discussion & Conclusion

Virtual Reality is an emerging technology that's rapidly developing and may be a device that will be very common in the near future. As the technology becomes more accessible it is likely that it would eventually be used for educational purposes and that is what prompted us to create an accessibility application for the potential VR online class platforms that may exist in the new future. While our initial idea is to operate everything within an VR online class setting with voice commands alone, that is not exactly he most efficient solution. Voice commands should not be a standalone input method as it is far too inefficient, but when used in conjunction with existing controls. Some things we could not implement as it was out of our scope like modularity in the voice commands. Our idea was that the user can create their own personal keywords so that it would be easier for them to use the application especially if the user has difficulty saying certain words. Our application could also improve on the accuracy as certain times the voice recognition would input a command more than once. Overall the main takeaway from this project is that voice commands alone do not improve efficiency for this particular application, however having an alternative input that can work in tandem with the default inputs can improve user experience and efficiency which is further supported by academic resources we researched.

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V. APPENDICES (ALL IMAGES IN GITHUB)

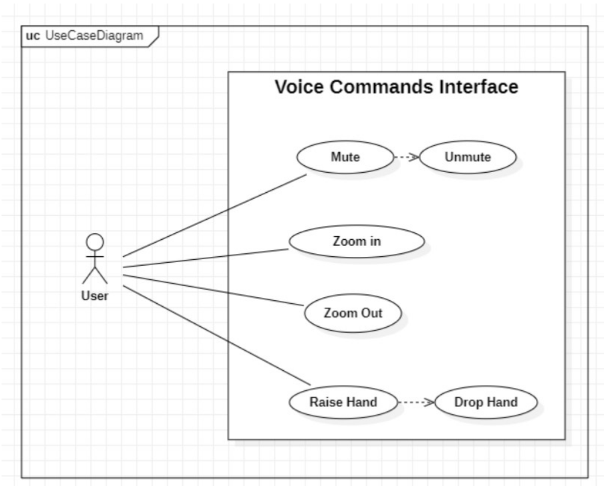

Figure 1. Original Use Case Diagram

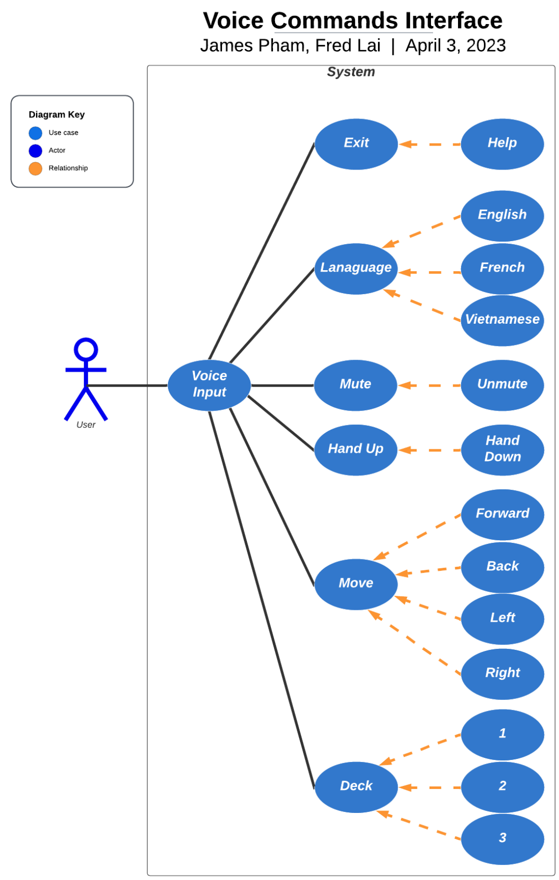

Figure 2. Improved Use Case Diagram

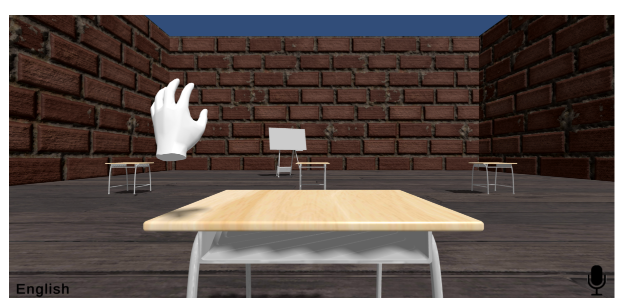

Figure 3. Wizard of OZ prototyping

Figure 4. Bodystorming

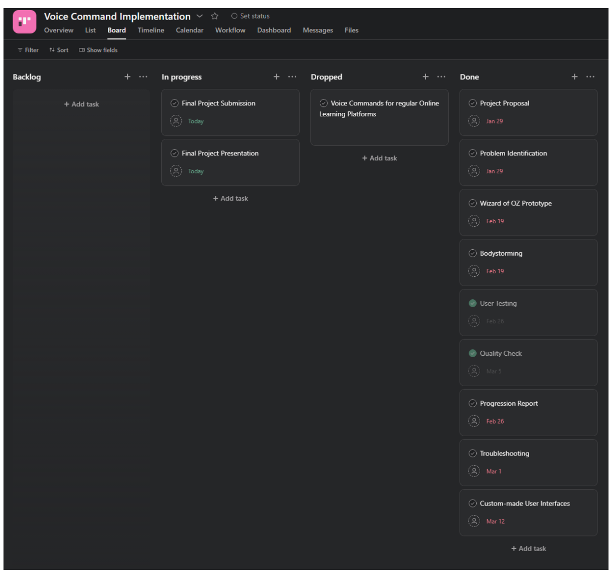

Figure 5. Kanban Chart

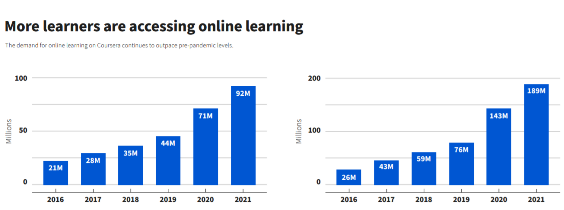

Figure 6. Online Learning Stats [6]

NASA-TLX Scoring Worksheet

Raw Scores and Weighting (According to the TLX Scoring Manual)

Instructions: Enter raw/unweighted rating scores in columns B - G.

*Note: Means for individual scores treat "0" as valid rather than missing data.

	B	C	D	E	F	G	Individual Scores							
							Weighted							Raw/Unweighted
User #	Mental	Physical	Temporal	Performance	Effort	Frustration	Mental	Physical	Temporal	Performance	Effort	Frustration	Mean*	Mean*
0/Ex	55	10	75	25	80	40	165	10	225	125	80	80	45.67	47.5
1	5	5	6	6	2	5	25	25	36	36	4	25	5.21	4.8333
2	3	1	3	9	3	2	9	1	9	81	9	4	5.38	3.5
3	1	1	1	10	1	1	1	1	1	100	1	1	7.00	2.5
4	2	1	2	8	4	2	4	1	4	64	16	4	4.89	3.1667
5	3	2	7	8	3	1	9	4	49	64	9	1	5.67	4
6	1	1	1	10	7	1	1	1	1	100	49	1	7.29	3.5

Group Score Results

Weighted		Raw/Unweighted	
Overall	5.91	**Overall**	4.17
Diagnostic Subscores		Diagnostic Subscores	
Mental	8.17	Mental	2.50
Physical	5.50	Physical	1.83
Temporal	16.67	Temporal	5.92
Performance	74.17	Performance	8.50
Effort	14.67	Effort	3.33
Frustration	6.00	Frustration	2.00

Figure 7. NASA TLX Survey

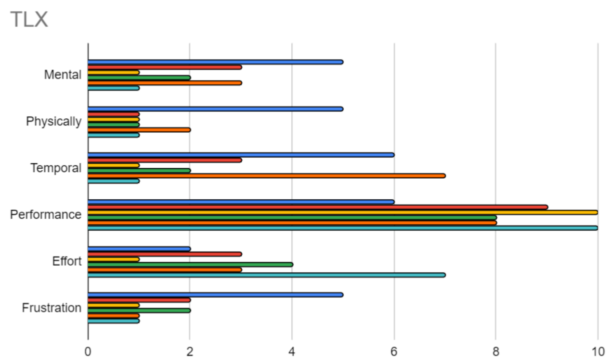

Figure 8. NASA TLX Graph

	Average	Gap	% out of total
Total:	86.4	46.6	65%
Realism	31.4	17.6	64%
Possibility to act	21.6	6.4	77%
Quality of interface	12.6	8.4	60%
Possibility to examine	11.8	9.2	56%
Self-evaluation of performance	9	5	64%

Figure 9. Presence Questionnaire

Paticipant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10				
	I think tha	I found the	I thought t	I think tha	I found the	I thought t	I would im	I found the	I felt very	I needed t	Score			
1	2	1	3	4	2	4	4	2	3	1	55			
2	4	1	4	1	2	4	5	1	4	2	75			
3	2	1	5	1	4	2	5	3	3	1	77.5			
4	4	2	5	2	5	1	4	1	4	2	85			
5	4	3	4	4	4	2	3	3	5	2	65		Average:	71.5

Figure 10. System Usability Survey

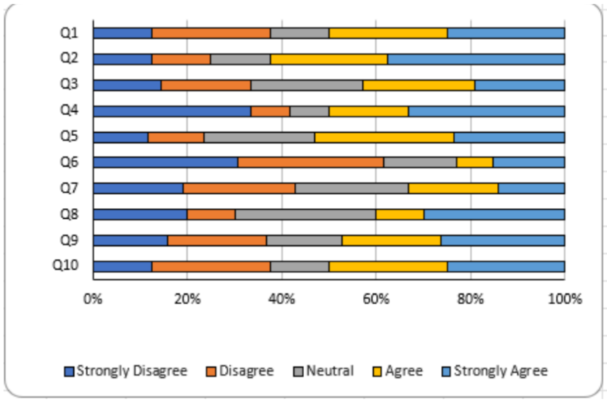

Figure 11. System Usability Survey Graph

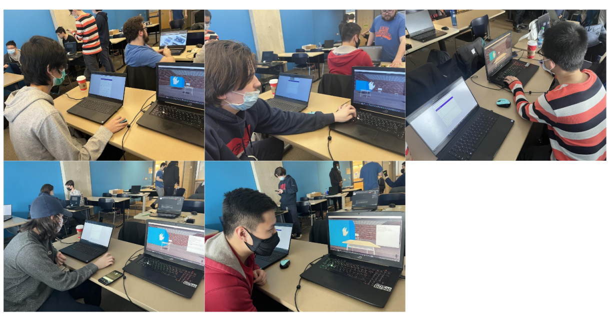

Figure 12. User Testing

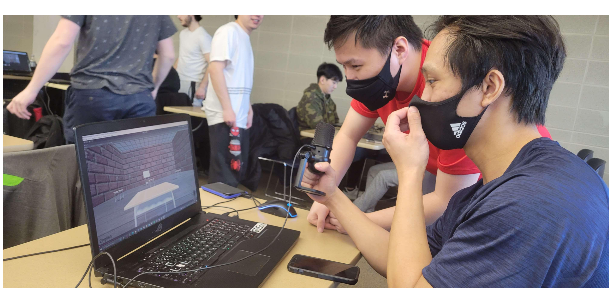

Figure 13. Final Lecture