EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2019)
S. Rizvic and K. Rodriguez Echavarria (Editors)

A Comparison of Navigation Techniques in a Virtual Museum Scenario

Ariel Caputo[1], Federico Borin[1] and Andrea Giachetti[1]

[1] Department of Computer Science, University of Verona, Italy

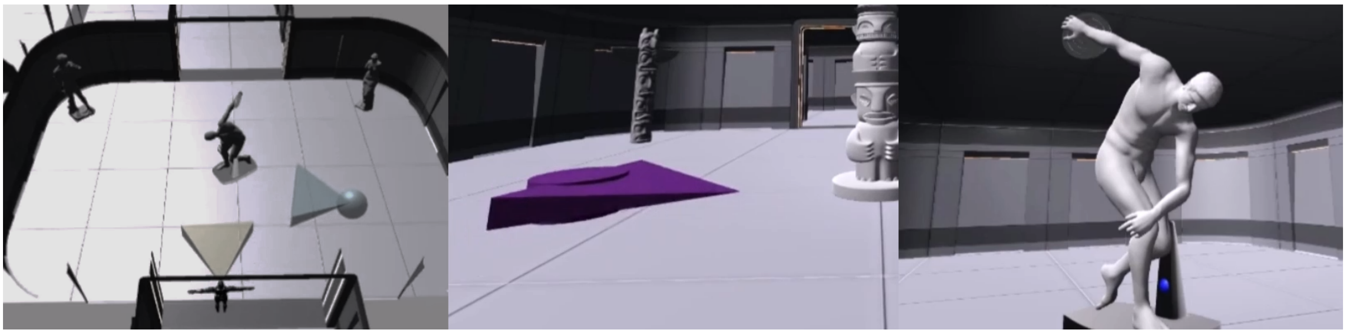


Figure 1: *Map Overview Teleport and Point and Teleport techniques in a search task set in a Virtual Museum*

Abstract

Thanks to the recent availability of low-cost immersive Virtual Reality (VR) devices, applications like Virtual Museums, where the users can explore fictional or recreated buildings hosting different artworks, are becoming increasingly popular. Different solutions can be implemented to enable users' navigation in an immersive Virtual Museum and the choice of the best one for a specific application is not easy, as several issues must be taken into account, like motion sickness, user's freedom, loss of orientation. In this work, we propose a novel locomotion technique called Map Overview Teleport, particularly suitable for exploration of virtual museums and compare it with standard ones in a specifically designed user study. The outcomes of the experiment give useful insights into the design of effective applications.

1. Introduction

Locomotion control is a core component of any application allowing user navigation in a virtual environment such as a Virtual Museum (VM). In VMs it is often a wanted feature, in order to give the user the ability to move from the current point to a new position and explore the environment and hosted artworks. The technique chosen for travel in a VM should be suitable for the task while, at the same time, avoiding known issues related to locomotion in VR.

The main issue of locomotion control in VR, and in particular for VMs, starts with the inability to map one-to-one the real world space with the virtual one. This led to the development of navigation techniques where the user moves indirectly the viewpoint, but he is actually static. If he perceives the continuous animation of the viewpoint on the HMD, this results in relevant problems related to bad sensory conflicts and sickness [LaV00]. VR applications usually avoid this by minimizing motion perception with simple workarounds. A partial solution is to restrict the user's field of view during the navigation to minimize the illusion of movement in the scene [FF16a]. This method, however, trades comfort with the immersion feeling. A very common solution is to remove completely the perceived motion by using the use of a point and teleport approach (PT) [BRKD16] totally eliminating the visual animation of the travel path. This solution is widely used in VMs [LV04, TSD*18, KTD17], but may lead to loss of context and orientation.

In this paper, we present a novel technique to control locomotion, called Map Overview Teleport (MOT), where the user selects the travel destination looking the scene from a different point of view in order to increase context information. The novel technique is a trade-off between the immersion, typical of a VR experience and a faster and less confusing orientation ability and may be suitable for VR applications focused on exploration.

DOI: 10.2312/gch.20191348

MOT is also thought to overcome some limitations of the PT technique, covering long distances in a blink.

The novel technique has been compared with PT in terms of efficiency and cyber-sickness effects on a complex exploration and search tasks in a VM, performed by 26 subjects with different gaming and VR experience.

2. Related Work

Locomotion in virtual reality presents many problems and many opportunities to innovate. Aside from traditional input devices like mouse, keyboard, and gamepad, the most obvious method of locomotion is simply walking around within the range of the positional tracking devices. This is possibly the most immersive and intuitive technique possible as it's the way we normally move around in the real world space. One problem presented by "walking" is the available space of the room. Physical obstacles such as walls and objects will prevent the user from advancing and could potentially hurt them, therefore, it is suitable just for very small environments. One solution to this problem is omnidirectional treadmills such as Virtuix Omni (https://www.virtuix.com), that simulate the translation of the user in the real world, and allows the movement in the virtual world through the treadmill sensors. This solution, while still being improved, is too expensive to be widely applied in all the VR applications requiring navigation.

For these reasons, practical solutions for VR replace physical travel, with the user's body physically translating or rotating to change the viewpoint with virtual travel "in which the user's body primarily remains stationary even though the virtual viewpoint moves" [LJKM*17].

Physical controllers can be used as well for indirect viewpoint control and several metaphors to control it with deviceless setups have been proposed as well.

Typical examples are the use pointing or gaze direction for steering control [BKH97]. Torso-directed steering has been also proposed to reduce the disorientation sensation of the gaze-directed navigation [LJKM*17].

The Lean-Directed Steering [BKLJP04,Jer15] metaphor uses the inclination of the body as input for the movement. When the user leans outside the normal center of gravity, the sensors determine the direction and speed of the movement. This method, however, requires the body to lean forward eventually increasing the feeling of cyber-sickness. An enhancement of the lean-directed steering technique is the Ninja-Run (also know as PenguFly [VKRF11]) metaphor. To compensate for the leaning forward of the head, the users' hands are also tracked. The three point in the space (i.e. two hands and the head) define a vector which determines the movement on a plane. This is also one of the biggest limitations of this technique: it's hard to think a way to expand it for a 3D (with a vertical movement) use case. While this technique offers some advantage it is largely limited to movements constrained to the horizontal plane.

Finger walk [YLD16] [KGMQ08] [VSBH10] is an interface thought with a long-term use in mind. To reduce fatigue, and, at the same time, give the feeling of walking. Finger walk uses a two fingers gesture to simulate the act of walking and the users are allowed to regulate the speed and frequency of each step.

The main issues with all kinds of virtual travel using a First Person perspective are related to the sickness due to the visual-vestibular mismatch and the potential loss of orientation. [LaV00] Some techniques propose to change viewpoints to reduce these effects, even if this may compromise the immersion.

Several authors studied methods to navigate in VE in third person [LEK*18] [MdAM*18] [STV08]. Third Person refers to a graphical perspective rendered from a fixed distance behind and slightly above the player character. This viewpoint allows users to see a more strongly characterized avatar. Most applications which implement a third person technique run well with gamepads as input methods. It could be a very easy technique to implement, with no need for motion-tracked controllers, but it's once again less immersive and can cause severe VR sickness due to the camera being anchored, but not centered, to the axis of the avatar's rotations.

Another technique usable for travel in VR is the one called Astral Body [DBS*17]. This technique combines first and third person perspectives. It mostly behaves like the two techniques described above: the first person is used when you need to interact with the environment and third person when you need to move around the environment. This may compensate for the limitations of each technique, resulting in a mixed technique that's easy to navigate and to interact with.

The World in Miniature manipulation technique (confront [SCP95]) is also being adjusted to work as a travelling mechanic too. In the miniaturized model of the environment, a small human avatar represents the user position and orientation in space. By manipulating it, the user can change its own position and orientation.

A totally different approach is to minimize the effects of the visual-vestibular mismatch, by completely removing travel simulation and use the idea of "teleport" to navigate the scene. The Point and Teleport technique [BRKD16] is based on instantaneous movements to interactively selected positions in the virtual world. It's a technique most suitable for applications which focus on exploration. A colored marker is rendered on screen and it's used to aim to the position where the user will end up to, after completing the teleport. The mark can be re-positioned (i.e., shifted further away or pulled closer in) using a controller's touchpad or analogue stick and the teleport is initiated by a single press of the trigger button. This technique is quite relevant because it lays the foundations for many variants that nowadays are largely used in the VR industry. Many VR games use a technique that slightly differs from the Point and Teleport implementation: in particular, the marker always snaps to the ground of the geometry of the scene and it's not possible to teleport into mid-air positions.

In our experiment, we tested an implementation of the first person Point and Teleport and proposed, as an alternative method, a hybrid one inspired by the World in Miniature metaphor that we call Map Overview Teleport, based on a change of viewpoint interactively performed when the user needs to be teleported. This allows a target position and orientation change with increased context information that we expect to allow a smoother navigation.

3. Methods and implementation

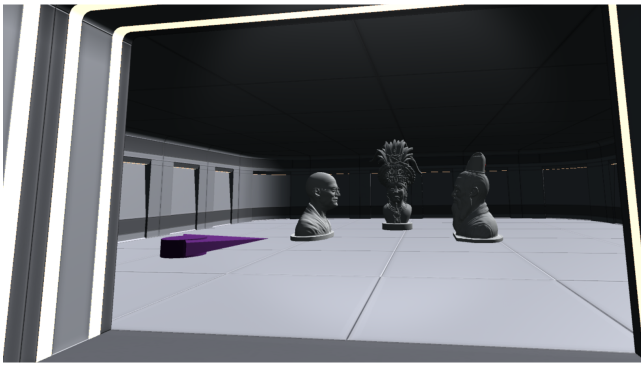
3.1. First Person Teleport (PT)

In our experiments, we implemented a PT locomotion control method similar to that described in [BRKD16], with direction specification. Differently from the original implementation, pointing and triggering of teleporting is done using a handheld controller.

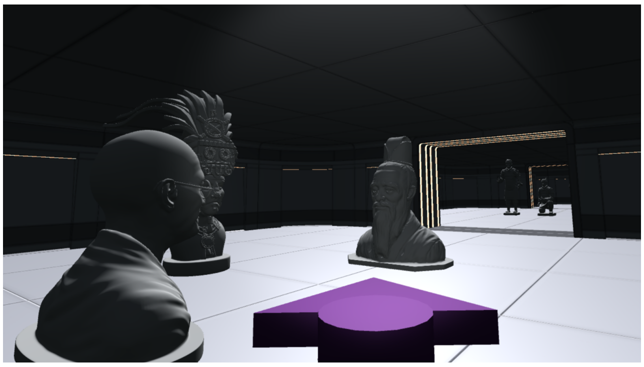
The user is given control of a visible 3-D cursor, with the aspect of a solid stylized arrow model, initially appearing in front of them. They can translate this arrow in the VE, on a plane that stays parallel to the ground. They can also rotate the cursor around its vertical axis. Upon pressing a button, the user can choose to be teleported in the position of the cursor, facing the direction in which the arrow pointed. Even if the cursor could penetrate the 3D mesh of the walls of the environment, the user is not allowed to teleport outside of the rooms and halls that compose the test environment. By doing so, the user's movement is basically limited to their own field of view.

In Figure 2 is shown the PT sequence of a single PT jump. We can see in Figure 2(a) that the user faces directly a trio of statues. They control the violet arrow cursor and move it on the left, pointing it towards the statue. When they press the interaction button they are teleported into the cursor position, and their viewpoint is shown in Figure 2(b). After the teleport, the cursor resets in front of the user, allowing a new placement and a new teleport jump.

This technique works better in close and mid-range. On the long range, it may be very difficult to point the cursor in the wanted direction, because of its perspective distortion due to distance.



(a) 3D cursor placement (violet arrow)



(b) Teleport is performed

Figure 2: *Sequence of PT usage.*

3.2. Map Overview Teleport (MOT)

The novel technique implemented, Map Overview Teleport combines the features of PT with the indirect interaction approach of the World In Miniature (WIM) technique [SCP95]. The WIM is born as a 3D manipulation technique but it's been enhanced to work as a navigation and travelling technique too. In the WIM travelling technique [WHB06] the user can interact with a 3D hand-held miniaturized model of the environment they're in. By manipulating a scaled down avatar in the 3D model the users can change their position and orientation in the environment. Map Overview Teleport works similar to the WIM, with the exception of the manipulation factor. The user can directly see the scene of the environment they're in, moving the perspective to a top-down viewpoint. While having this high ground perspective, the user can move, with the help of a controller, a 3D cursor. The cursor looks like a simple sphere with a pyramid attached with the pyramid representing the field of view and the frustum of the rendering camera. As with the previous PT technique, the user can teleport with the push of a button to the position of the cursor, facing the direction it points to. The field of view pyramid on the cursor it's a helping tool to understand what the user will be able to see right after completing a teleport.

Switching to a top-down perspective sacrifices a higher sense of physical presence in the environment [UAW*99], but it allows for a quicker and easy way to travel across large distances. In the test samples, it's used to travel directly from room to room, but it could also be used for even farthest destinations, such as building, cities and Countries (with the help of a scaling camera acting accordingly).

As with our PT technique implementation, even if the cursor can pass through walls, and the user cannot teleport out of the environment bounds. We expected this technique to work extremely well when travelling from room to room as we thought it could easily be done in a single jump.

In Figure 3 it is shown the sequence of a single MOT teleport jump. In Figure 3(a) the user is facing the statue and wishes to change the point of view. By pressing the designated button on the controller, the user point of view changes to the top-down perspective (Figure 3(b)). In our implementation the transition is immediate with no particular effect. The camera moves behind the avatar and high enough so that the whole environment could fall inside the view frustum. The camera, however, doesn't point in a fixed direction and the user is able to recenter it on the preferred point simply by moving the head. After activating this view, the user can now see the layout of the environment and the content of the rooms. The cyan pyramid position starts at the current user's point of view. While in this mode, they can move the cursor around, and manipulate its orientation. In Figure 3(c) the cursor is placed on the back of the statue, almost diametrically opposed to the starting position. The cyan pyramid now represents the cursor field of view, while the yellow pyramid marks the cursor position at the time the MOT technique was called. With the pressure of the same interaction button as before, the user is once again projected in a first-person perspective (see 3(d)) at the coordinates where the cyan pyramid cursor was, looking towards its direction.

3.3. Gamepad Controlled Steering (GCS)

To verify the ability of both PT and MOT to reduce sickness effect we also implemented and compared another simple navigation method translating the viewpoint with the controller, keeping a first-person perspective and allowing the viewpoint rotation by rotating the head. This technique results in a significantly more immersive experience than the other two tested techniques, but has been shown to be problematic in terms of cyber and motion sickness [HR92] [MDS17].

4. Experiment Design

The goals of our experiments are to verify if the MOT provides better navigation experience and is preferred by different users, compared to the widely used PT, and to check if it is successful in reducing sickness effects compared to GCS. For this experiment, we used a commercial VR kit (i.e. Oculus Rift) and standard desktop PC.

We defined and implemented a complex exploration and search task and selected a set of subjects suitable for this study.

4.1. Hardware Setup

For this study, we relied on the Oculus Rift device, as a means of access to the VE. The Oculus Rift native controllers, the Oculus Touch devices, were also used as input devices. The whole VE was created and managed with the Unity3D Engine (`www.unity3d.com`). No other software or libraries were used in the process.

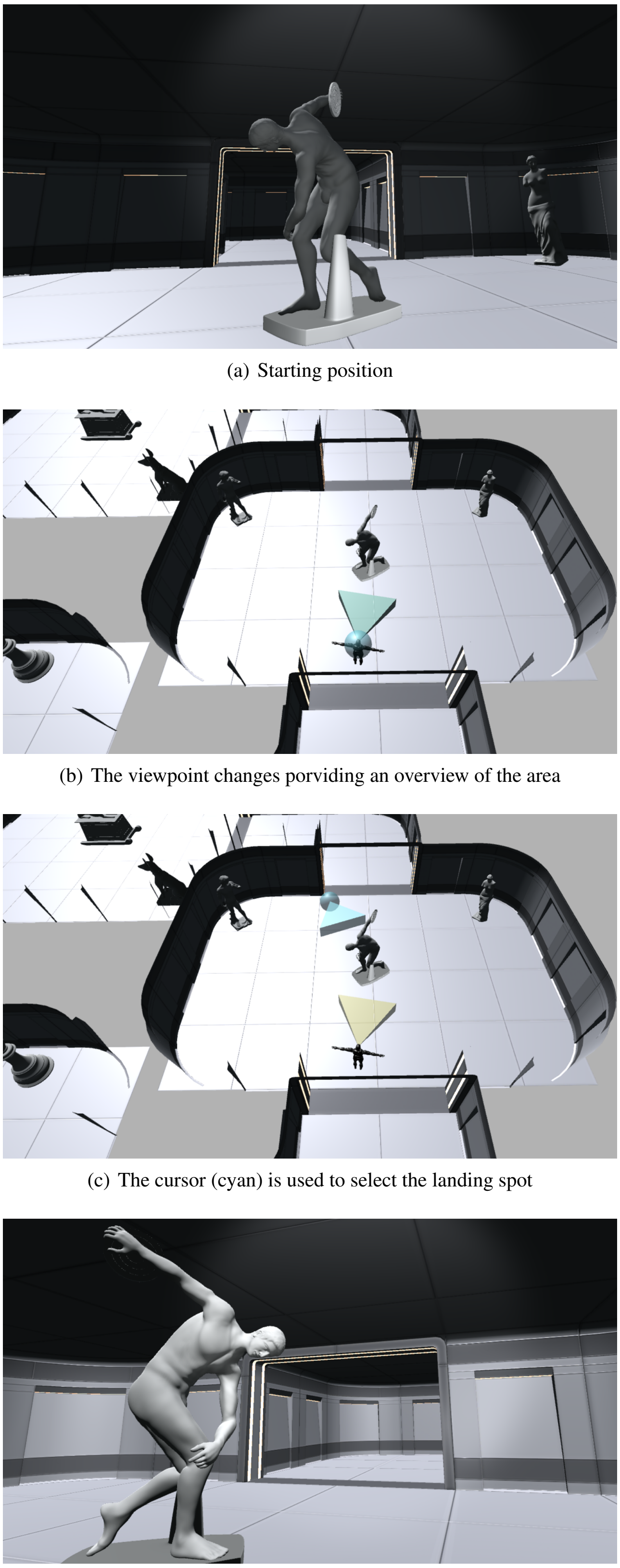
We mapped the controls with the standard configuration used in many video games. The left thumbstick joypad controller controls the movement and positioning of the navigation techniques' cursor. The right thumbstick joypad controller controls the rotation of the cursor. Only a button was used beside the two thumbstick controllers. The right trigger button is situated in the front of the right Touch Controller and can be triggered with the pressure of the right forefinger. Since many applications and games use this button as the main button for interaction, we also decided to map the interaction button on the right trigger.

4.2. Evaluation Task

The task was set in a virtual fictional museum. The scene is composed of a training room, and a series of ten exhibit rooms, connected by small corridors, forming a long one-way path.

The user starts every run in the training room, in which they can be taught the navigation technique for the task and can actively familiarize with the input system, trying for themselves some teleport jumps. When the user feels comfortable enough with the navigation system, they are moved into the first room, where the real test takes place.

Each of the ten rooms presents a texture-less model of a statue



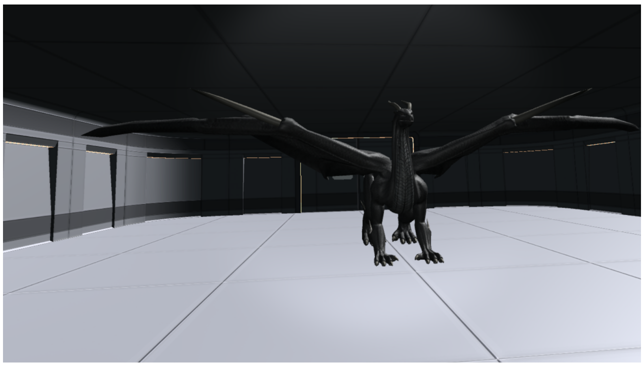
(a) Starting position

(b) The viewpoint changes porviding an overview of the area

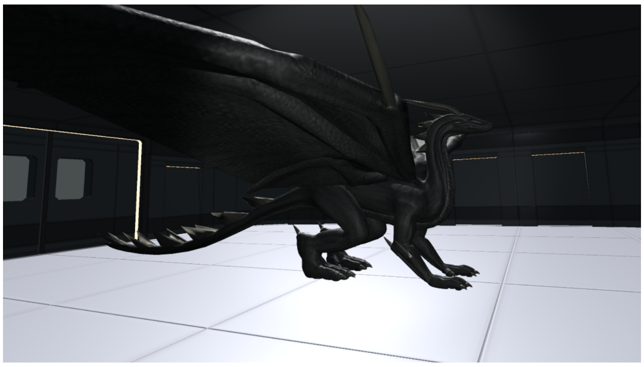
(c) The cursor (cyan) is used to select the landing spot

(d) The teleport is performend and the viewpoint returns to first person

Figure 3: *Sequence of MOT usage.*



(a) The user enters one of the rooms



(b) The user moves around to find a colored spot on the statue

(c) The user identifies the spot and can proceed to the next room

Figure 4: *Sequence of the sub-task: "Find the spot on a statue"*

in the middle, that can be examined moving all around it. Most of the statues are low-poly (3D meshes with a relatively low number of polygons) and without in-deep details, however, they present complex geometric shapes that don't allow to easily examine their entirety with too few changes of viewpoints. Each of the statues presents a colored spot. The spot is realized as a 3D sphere nestled inside the statue.

The user was asked to move around every room in order to spot the colored mark on it. This searching task was though to test the user's control over the navigation technique by constantly asking

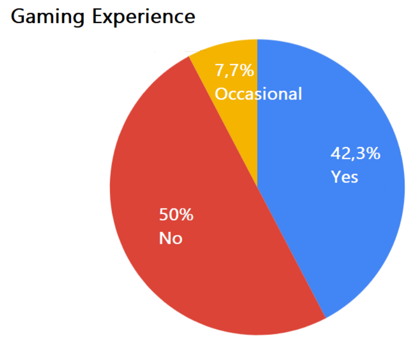


Figure 5: *Test subjects' gaming experience distribution.*

for new viewpoints around the statues, and to engage the user long enough to have them manifest possible cyber-sickness symptoms.

In this search task, the user has to travel to a specific goal (the spot) within the environment. Since the user does not know the position of their target, we can further categorize the task as "naive search" [DS96]. Naive search is very similar to the task of exploration, in which the user is freely browsing the environment obtaining information about objects within the world and building up knowledge of the space [BKLJP04]. The difference is that the statue positions are important visual clues that bind and focus on the exploration.

Once the user successfully identifies the marker, he may proceed to the next room and the next statue, until he completes the exploration of the ten rooms.

The marker search sub-task is summarized in Figure 4. In Figure 4(a) the user just entered the room and faces the statue. The spot can be anywhere on the statue's surface. In Figure 4(b) the user tries to observe the statue from a different point of view. Many users strategy for the sub-task consisted of examining the statue from non-overlapping views. In the example shown in Figure 4(b), no spot is visible. The user then takes another teleport jump, going behind the dragon statue (Figure 4(c)) where they can finally spot the sphere on the back of the left hind leg.

4.3. Users Sample and hypotheses tested

We asked a group of 26 subjects to perform the described task with both the FP and MOT. To counterbalance order-bias effects, half the users started with FP and then switched to MOT while the vice versa happened for the other half.

The age of the subjects was between 21 and 34 years, with an average user who's 26 years old.

As shown in Figure 5, half of the users asserted that they don't (or very rarely) use video games or they don't have any confidence with game controllers 5. This allows testing specific hypotheses on the usability of the technique for different categories of subjects. We hypothesize that gamers have better spatial abilities.

We measured the task completion time for each subject on each condition. Furthermore, after each run, we made the subject compile a questionnaire about the amount of motion sickness felt during the experiment, and to express a preference for the technique providing the best navigation experience.

For the questions about the sickness, we used a variant of the Questionnaire for the Assessment of the Multiple Dimensions of Motion Sickness [GMM*01]. In our questionnaires, we aimed to measure on a Likert scale, from 1 (none) to 5 (severe), the user discomfort. We split such feeling in 12 categories, namely: stomach discomfort, irritation, fainting, sweating, disorientation, fatigue, overheating, dizziness, vertigo, nausea, puke feeling, uneasiness.

With the recorded data we aimed at testing the following hypotheses:

1. MOT provides better locomotion efficiency (lower task completion time)
2. Subject with gaming experience can complete the task with more efficiency
3. MOT is easier to use for non-expert users, i.e. for user with lower spatial abilities.
4. MOT is preferred to PT as it gives a clearer understanding of the museum layout

In order to verify that MOT (as PT) reduced sickness with respect to GCS we asked the subjects, after the completion of the experiment, to repeat the task using the GCS method and to fill a sickness questionnaire including GCS. We separated this test from the comparison between PT and MOT in order to avoid biases in the PT vs MOT evaluation.

5. Results

Table 1 shows the average completion times for each technique and category of users in our experiment. As normality hypothesis required for a t-test wasn't satisfied, we performed a Wilcoxon signed-rank test to look for significant differences in time between MOT and PT. The results showed no significant differences ($p > 0.05$) between the time averages, therefore, our first hypothesis (**Section 4.3**) couldn't be verified.

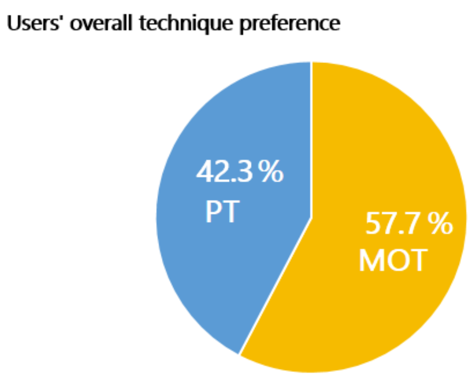


Figure 6: *Percentage of users that preferred a technique over the other.*

		All	Gaming Exp.	No-gaming Exp.
PT	Time (s)	248,2	199,3	297.1
	Std. Dev.	82,7	72,4	36,9
MOT	Time (s)	225,2	182,3	258,9
	Std. Dev	54,9	87,8	74,7

Table 1: *Average time performances between user categories: all users, users with gaming experience, users without gaming experience.*

However, if we consider the two subgroups of subjects with or without gaming experiences, we can verify that some of our hypotheses are supported by the results.

We compared the task completion time performances of the two users' subsets when using the MOT technique, by performing a t-test. We found a significant difference ($p = 0.002$) in favour of the gaming experience category that presented a lower average task execution time

For the PT technique, we had to use the non-parametric Wilcoxon test again. In this case as well, the result shows a significant difference ($p = 0.0036$) in favour of users with gaming experience.

These two results confirmed our second hypothesis: people experienced in gaming attain, on average, a lower execution time, possibly due to more developed spatial abilities.

If we compare the average task completion time within the two subsets, we have another significant result: while the test for gaming experience category didn't show any significant difference be-

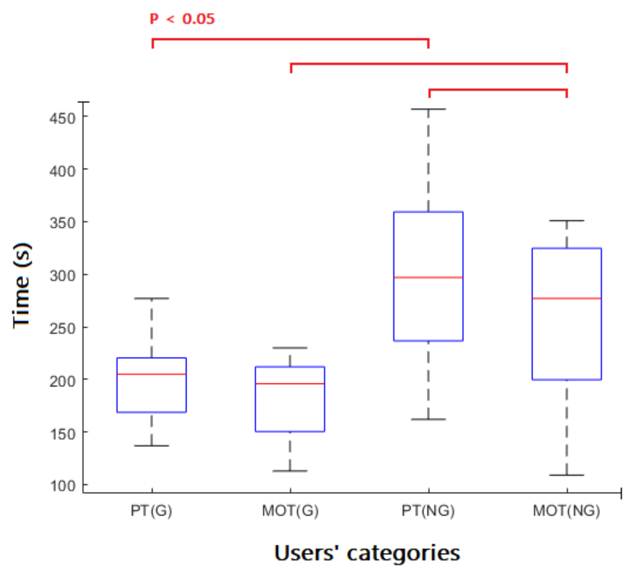


Figure 7: *Boxplot of subjects' categories per technique: all users (All), users with gaming experience (G), users with no gaming experience (NG).*

tween PT and MOT ($p > 0.05$ in a Wilcoxon test) the contrary was found with a t-test on time averages of PT vs. MOT ($p = 0.0373$).

Our hypothesis is that this might be due to the potentially higher skill required for the PT technique in placing the cursor in a less favourable viewpoint perspective compared to MOT. With this kind of perspective and working with a task that requires 3D spatial cognition, PT is probably more comfortable for gamers. On the other hand, with the MOT technique, thanks to the viewpoint change, the task is performed nearly on a 2D view of the environment layout. This makes the task possibly more convenient for users without gaming experience, evening the difference in skills with the experienced ones.

This fact suggests that MOT is a favourable technique for people with limited spatial ability, supporting our third hypothesis. We summarized these results in a boxplot (Figure 7) and marked the differences we found between the subjects' categories.

After performing the two tests, users were asked to indicate the preferred navigation technique. As shown in Figure 6, more than half of the users (57,7%) indicated the MOT technique as a better candidate overall against its competitor PT. The difference resulted statistically significant with $p<0.05$ with a Pearson's chi-squared test. This result, even if with a small margin, supports our fourth hypothesis.

By analyzing the part of questionnaire data related to the cybersickness, we are not able to identify significant differences between PT and MOT in any of the parameters described in **Section 4.3**. However, the comparisons between GCS and the two teleport based methods confirm the fact that GCS is not well suited as a navigation technique due to issues related to cyber-sickness. In fact the users reported higher scores for stomach discomfort and dizziness for the GCS against both PT and MOT (tested with GLM, $p<0.005$) as shown in Figure 8 and Figure 9. For the rest of the symptoms, no significant differences were found.

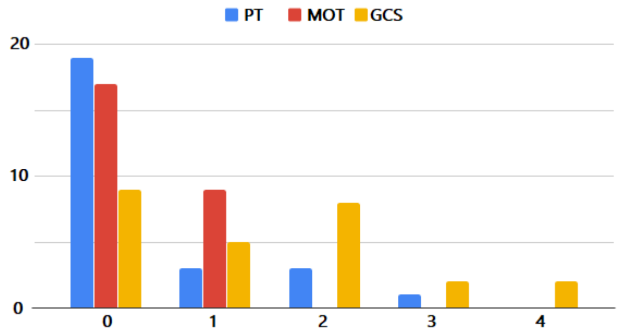


Figure 8: *Questionnaire scores for the dizziness symptom from 0, no effect perceived, to 4, strong effect perception (Likert scale on x-axis and number of users per score along y-axis).*

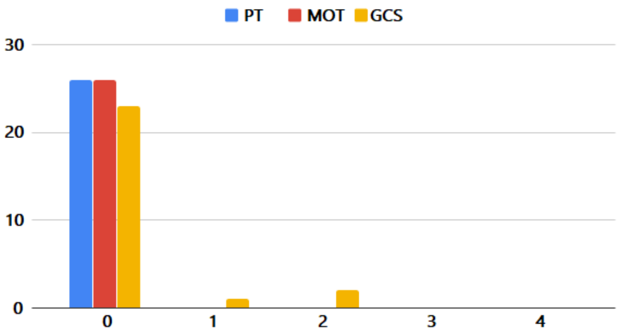


Figure 9: *Questionnaire scores for the stomach discomfort symptom from 0, no effect perceived, to 4, strong effect perception (Likert scale on x-axis and number of users per score along y-axis).*

6. Discussion

Virtual Reality-based museum exploration presents non trivial navigation issues, as it is necessary to find an optimal trade-off between the reduction of motion sickness effects, that may be relevant in a task requiring significant user's movements in a large space, and the loss of orientation that may derive by teleport techniques often used to avoid sickness.

The novel navigation technique proposed in this paper, Map Overview Teleport (MOT) can be a good trade-off solution as it gives contextual information for navigation while controlling and executing teleport for large and fast motion avoiding the sickness related to first person navigation with continuous motion animation.

Experimental results show that the novel method is appreciated by the users. The user feedback confirms that direct teleportation across the map and the ability to see the map itself are considered helpful for navigating quickly unknown spaces. One achievement that makes the proposed locomotion method particularly suitable for navigation in VMs, is the fact that it allowed, in the experimental tests, a more effective exploration for people with limited spatial abilities (i.e. non-gamers). Experiences in VMs should, in fact, be optimal for generic audience, with no need for specific training or skills. So, while for games or VR training it may be acceptable to assume that the user can get specific spatial abilities or resistance to cyber-sickness, this is not the case for tours in VMs. One possible advantage of the MOT technique is that it allows large movements in a single jump, such as room to room, or even on a larger scale. This ability, however, isn't necessarily in conflict with the freedom to move around in the near local space with a PT-like technique. In fact, some users commented that the two techniques were, in fact, useful in different contexts, with PT being more immersive in what they're doing, and MOT being more helpful on long distance travels. It is clear that commercial VM solutions can then implement combinations of different navigation techniques creating a more general solution to the navigation problem for a variety of immersive VEs scenarios.

We plan to investigate combined locomotion solutions in future works as well as an extension of the MOT to make possible navigation in more complex layouts (e.g multi-level buildings) to provide further mobility and provide further advantages compared to the state of the art techniques. Another future direction of our research is related to the comparison of teleport solutions, totally avoiding viewpoint animations for large displacements like the PT and MOT implementations used in this paper, with standard steering solution using smart methods to reduce vection and motion sickness as proposed in [FF16b].

7. Conclusions

We presented a novel navigation technique for the exploration of immersive virtual environment based on a combination of external view and teleport and the outcomes of a user test trying to point out potential advantages of the methods in a user scenario. We believe that the proposed method is particularly suitable for virtual museum applications and we plan to implement it in end-user applications in the near future.

Acknowledgments. This work has been partially supported by the project MIUR Excellence Departments 2018-2022.

References

[BKH97] Bowman D. A., Koller D., Hodges L. F.: Travel in immersive virtual environments: An evaluation of viewpoint motion control techniques. In *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality* (1997), IEEE, pp. 45–52. 2

[BKLJP04] Bowman D., Kruijff E., LaViola Jr J. J., Poupyrev I. P.: *3D User interfaces: theory and practice, CourseSmart eTextbook*. Addison-Wesley, 2004. 2, 5

[BRKD16] 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* (2016), ACM, pp. 205–216. 1, 2, 3

[DBS*17] Debarba H. G., Bovet S., Salomon R., Blanke O., Herbelin B., Boulic R.: Characterizing first and third person viewpoints and their alternation for embodied interaction in virtual reality. *PloS one 12*, 12 (2017), e0190109. 2

[DS96] Darken R. P., Sibert J. L.: Wayfinding strategies and behaviors in large virtual worlds. In *CHI* (1996), vol. 96, pp. 142–149. 5

[FF16a] Fernandes A. S., Feiner S. K.: Combating vr sickness through subtle dynamic field-of-view modification. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)* (March 2016), pp. 201–210. doi:10.1109/3DUI.2016.7460053. 1

[FF16b] Fernandes A. S., Feiner S. K.: Combating vr sickness through subtle dynamic field-of-view modification. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)* (2016), IEEE, pp. 201–210. 8

[GMM*01] Gianaros P. J., Muth E. R., Mordkoff J. T., Levine M. E., Stern R. M.: A questionnaire for the assessment of the multiple dimensions of motion sickness. *Aviation, space, and environmental medicine 72*, 2 (2001), 115. 6

[HR92] Hettinger L. J., Riccio G. E.: Visually induced motion sickness in virtual environments. *Presence: Teleoperators & Virtual Environments 1*, 3 (1992), 306–310. 4

[Jer15] Jerald J.: *The VR book: Human-centered design for virtual reality*. Morgan & Claypool, 2015. 2

[KGMQ08] Kim J.-S., Gračanin D., Matkovi'c K., Quek F.: Finger walking in place (fwip): A traveling technique in virtual environments. In *International Symposium on Smart Graphics* (2008), Springer, pp. 58–69. 2

[KTD17] Kersten T. P., Tschirschwitz F., Deggim S.: Development of a virtual museum including a 4d presentation of building history in virtual reality. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 42* (2017), 361. 1

[LaV00] LaViola Jr. J. J.: A discussion of cybersickness in virtual environments. *SIGCHI Bull. 32*, 1 (Jan. 2000), 47–56. URL: http://doi.acm.org/10.1145/333329.333344, doi:10.1145/333329.333344. 1, 2

[LEK*18] Lugrin J.-L., Ertl M., Krop P., Klüpfel R., Stierstorfer S., Weisz B., Rück M., Schmitt J., Schmidt N., Latoschik M. E.: Any âĂIJbodyâĂİ there? avatar visibility effects in a virtual reality game. In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)* (2018), IEEE, pp. 17–24. 2

[LJKM*17] LaViola Jr J., Kruijff E., McMahan R., Bowman D., Poupyrev I.: *3D user interfaces: theory and practice*. Addison-Wesley Professional, 2017. 2

[LV04] Lepouras G., Vassilakis C.: Virtual museums for all: employing game technology for edutainment. *Virtual reality 8*, 2 (2004), 96–106. 1

[MdAM*18] Medeiros D., dos Anjos R. K., Mendes D., Pereira J. M., Raposo A., Jorge J.: Keep my head on my shoulders!: why third-person is bad for navigation in vr. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology* (2018), ACM, p. 16. 2

[MDS17] Munafo J., Diedrick M., Stoffregen T. A.: The virtual reality head-mounted display oculus rift induces motion sickness and is sexist in its effects. *Experimental brain research 235*, 3 (2017), 889–901. 4

[SCP95] Stoakley R., Conway M. J., Pausch R.: Virtual reality on a wim: interactive worlds in miniature. In *CHI* (1995), vol. 95, pp. 265–272. 2, 3

[STV08] Salamin P., Thalmann D., Vexo F.: Improved third-person perspective: a solution reducing occlusion of the 3pp? In *Proceedings of The 7th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry* (2008), ACM, p. 30. 2

[TSD*18] Tsita C., Sinanis A., Dimitriou N., Papachristou K., Karageorgopoulou A., Drosou A., Tzovaras D.: A Configurable Design Approach for Virtual Museums. In *Eurographics Workshop on Graphics and Cultural Heritage* (2018), Sablatnig R., Wimmer M., (Eds.), The Eurographics Association. doi:10.2312/gch.20181349. 1

[UAW*99] Usoh M., Arthur K., Whitton M. C., Bastos R., Steed A., Slater M., Brooks Jr F. P.: Walking> walking-in-place> flying, in virtual environments. In *Proceedings of the 26th annual conference on Computer graphics and interactive techniques* (1999), ACM Press/Addison-Wesley Publishing Co., pp. 359–364. 3

[VKRF11] Von Kapri A., Rick T., Feiner S.: Comparing steering-based travel techniques for search tasks in a cave. In *2011 IEEE Virtual Reality Conference* (2011), IEEE, pp. 91–94. 2

[VSBH10] Valkov D., Steinicke F., Bruder G., Hinrichs K. H.: Traveling in 3d virtual environments with foot gestures and a multi-touch enabled wim. In *Proceedings of virtual reality international conference (VRIC 2010)* (2010), pp. 171–180. 2

[WHB06] Wingrave C. A., Haciahmetoglu Y., Bowman D. A.: Overcoming world in miniature limitations by a scaled and scrolling wim. In *3D User Interfaces (3DUI'06)* (2006), IEEE, pp. 11–16. 3

[YLD16] Yan Z., Lindeman R. W., Dey A.: Let your fingers do the walking: A unified approach for efficient short-, medium-, and long-distance travel in vr. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)* (2016), IEEE, pp. 27–30. 2