# Mini-map positioning for Virtual Reality environments in hyperbolic space

**Scott Jochems, s.a.jochems@student.tudelft.nl**
**Supervisors: M. Skrodzki and R. Bidarra**

TUDelft

## 1. Background

Virtual reality is widely used to teach complex topics [1]. The holonomy team has been developing a game that allows players to navigate through rooms connected by hyperbolic geometry, see figure 1. While navigating an unknown space can already be difficult, this difficulty only increases when the player finds themselves in a non-Euclidean space. Current research has indicated a mini-map is one of the most useful tools to help players navigate [2], [3]. These papers focus on navigational performance while using a mini-map. They do not consider whether the position of the mini-map has an influence on the player's performance.

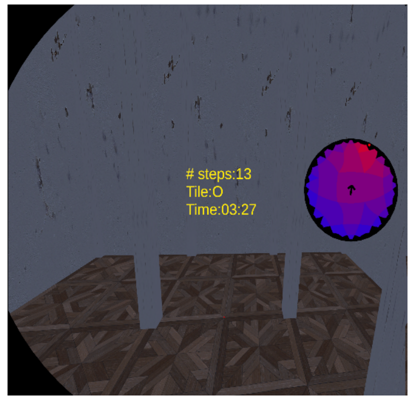


**Figure 2: This image shows what the mini-map and the environment look like on the HUD as seen from the left eye**

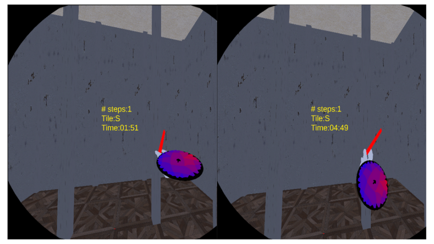

**Figure 3: This image shows what the mini-map and the environment look like with the player-fixed mini-map as seen from the left eye**

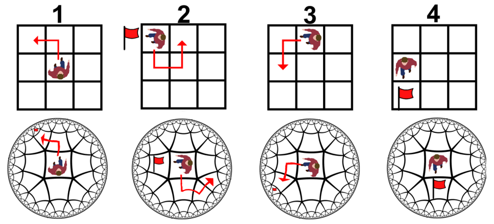


**Figure 1: Real world vs hyperbolic movement in the tutorial**

## 2. Research problem

**What effect does the position of the mini-map have on the player's navigational performance in the hyperbolic space?**

Two main positions have been chosen for the mini-map that differ on one core feature:

- A mini-map on the Heads-Up Display (HUD), as seen in figure 2.
- A player-fixed mini-map, as seen in figure 3.

On the HUD, meaning it stays in the same position in the player's vision. Player-fixed, meaning it is connected to the player's right hand, allowing the player to move it anywhere within their vision.

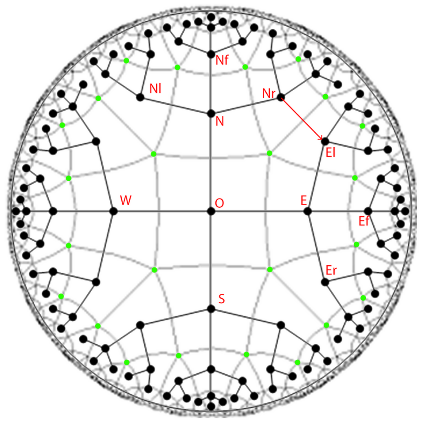


**Figure 4: This image shows the graph on which the virtual world is based using the black lines. The rooms of the virtual world are indicated using gray lines. The center point is called the origin and from this point, all rooms are defined. The rooms are first defined by a cardinal direction and then the direction taken from that room (Left "l", Forward "f", Right "r"), as seen from the red letters. The red arrow indicates a step in which the player's orientation would turn. The green vertices indicate where a player would see pillars in the world.**

## 3. Methodology

**Implementation**

Both mini-maps have their rotation locked and have an arrow on the map indicating the direction the player is facing. To make this work intuitively in hyperbolic geometry we need to utilize the graph in figure 4. Going north-right "Nr" and right is translated to east-left "El" which we can visualize by rotating the mini-map by 90 degrees. The HUD mini-map can be seen in figure 2, and the player-fixed mini-map can be seen in figure 3.

**Experiment**

The question now becomes if one of the positions has a bigger impact on the player's navigational performance within the hyperbolic space than the other. To answer this we set up a player study with 30 participants. They are split into two equally sized groups, one will run the experiment with the HUD mini-map, the other with the player-fixed mini-map.

Players will fill in a form and be given an information sheet before the experiment. They will then partake in a short tutorial, the path of the tutorial can be seen in figure 1, before doing 3 different levels. After they will be given another form to fill in.

## 4. Results

The pre-test results showed both groups had similar distributions to eachother in all categories. The following data was asked in the pre-test form:

- Gender
- Age
- Study
- Experience 3D video games
- Experience with VR
- Experience with hyperbolic geometry

Only the experience a player had previously with VR indicates an effect on the player's performance, as seen in figure 8.

Players were measured on the following metrics:

- Time and amount of steps per level
- Time and steps improvement per level
- Total time and total steps

On these results, an ANOVA was run. After this the outliers were removed and an ANOVA was run again. The results can be found in figures 4, 5, and 6.

Lastly, on the evaluation form, three additional statements were made on which players rated from a 1 to 6 on how much they agreed with the statement:

- My navigation toward the objective went well
- The minimap was very helpful with finding the objective.
- The minimap was easy to read and understand.

On these three statements, a Wilcoxon rank sum test was run which indicated no significant difference between the groups.

## 5. Conclusion

In conclusion, our research suggests that the position of a mini-map in a VR game using hyperbolic space does not affect a player's navigational performance. Small differences can be observed, while people naturally know the HUD mini-map better, in some cases the player-fixed mini-map performs better. The best position might rather depend on the choice of the player. The variance difference indicates that the player-fixed mini-map is the most likely to align with the average player's preference.

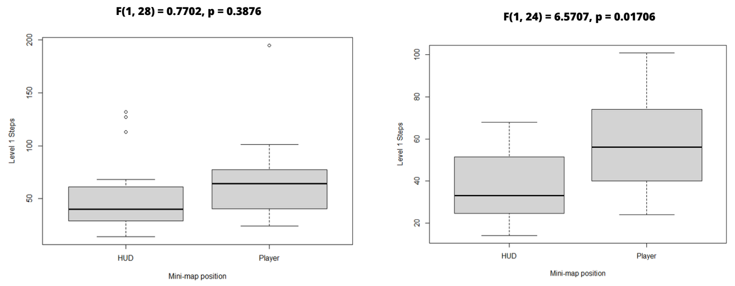


**Figure 5: Level 1 steps results before (left) and after (right) the removal of the outliers**

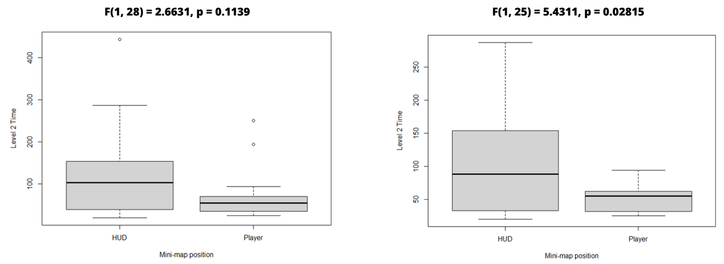


**Figure 6: Level 2 time results before (left) and after (right) the removal of the outliers**

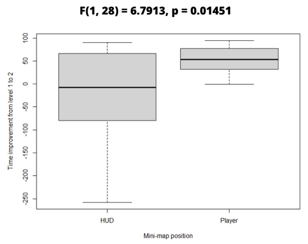


**Figure 7: Time improvement from level 1 to level 2,**

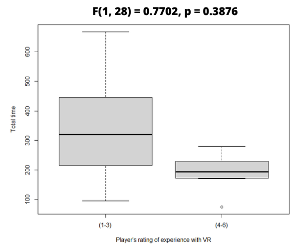


**Figure 8: VR experience effect on performance**

## 6. Future work

A variant of this study can randomize the order in which levels 1, 2, and 3 are given to the player. This would eliminate the effect that the difficulty of the levels has on the player's performance.

To test the player's preference a within-player test can be held. Two groups would be made, one group plays with the HUD mini-map first, and then after some time they play with the player-fixed mini-map and give their opinion on both. The other group would play with the player-fixed mini-map first and the HUD mini-map later.

Another situation in which the mini-map's effect can be tested is when it is used in combination with the environment. The environment can be populated with landmarks which can then be shown on the mini-map as well. This will allow players to navigate using the virtual environment alongside the mini-map.

## References

[1] Gan, W., Mok, T.-N., Chen, J., She, G., Zha, Z., Wang, H., Li, H., Li, J., and Zheng, X. (2023). Researching the application of virtual reality in medical education: one-year follow-up of a randomized trial. BMC Medical Education, 23(1). Cited by: 1; All Open Access, Gold Open Access, Green Open Access.

[2] Kraus, M., Schafer, H., Meschenmoser, P., Schweitzer, D., Keim, D. A., Sedlmair, M., and Fuchs, J. (2020). A comparative study of orientation support tools in virtual reality environments with virtual teleportation. page 227 – 238. Cited by: 3; All Open Access, Green Open Access.

[3] Kotlarek, J., Lin, I.-C., and Ma, K.-L. (2018). Improving spatial orientation in immersive environments. In Proceedings of the 2018 ACM Symposium on Spatial User Interaction, SUI '18, page 79–88, New York, NY, USA. Association for Computing Machinery.