How easy is it for players to complete a navigational task within a Non-Euclidean virtual environment?

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1 Proposal

Within the games industry, there is a concept called Euclidean and Non-Euclidean geometry. Euclidean geometry is used in the study of flat surfaces. Meaning, a straight line is the shortest possible line between two points. Whereas Non-Euclidean geometry uses curved surfaces or spherical shapes. Which then allows for the measurement of the shortest distance between two points whilst also using a spherical object [2]. An example of a game that does this technique is "**Portal**" and how it creates the look of its dual portal system. It gives the player the ability to places down two portals at two different points of the level and allows them to see through the primary portal and see the surroundings of the secondary portal whilst being at the angle of the player's perspective. Another example of how it can be utilised can be seen in the game "**Antichamber**" with how it generates looping corridors, portals and having multiple scenes existing in the same space through the use of stencil buffers. I'll explain their purpose later in the paper. But for now, I shall point your focus more toward the more psychological effects that Non-Euclidean geometry may provoke and how these games make the average user feel when playing them.
Referring back to **Antichamber**, this game most certainly toys with the idea of generating abstract ways of making the player feel uneasy and disorientated. But also gives the player a sense of wonder when discovering the mechanic of the puzzle as they literally make you think outside (or inside?) the box.

2 Research Question

I intend on this paper to delve further into Non-Euclidean techniques and levels of Agency that the user possesses when they are given these such aspects. I'm also considering that the data acquired from the experiment be used to help in the production of other applications be that, Virtual Reality or in other games that wish to use Non-Euclidean elements. So with the experiment, I aim to test two hypotheses:
1. There are a set amount of tasks that the user can complete before they become disorientated;
2. Users that have less experience with games will perform more efficiently in the experiment compared to those that do;

3 Background

3.1 Metric Cognitive Map Testing

When looking at the more psychological effects with using Non-Euclidean geometry, there has only been a very small handful of academic research tests that had been conducted, however not by using a video game as a ground to work on. Within the paper "Journal of Experimental Navigation: Non-Euclidean navigation" [4], it is mentioned that they conducted a test which involved an assortment of rats and a maze that was constructed on an elevated, spherical surface. This test were to gather behavioural evidence for **metric cognitive maps**.

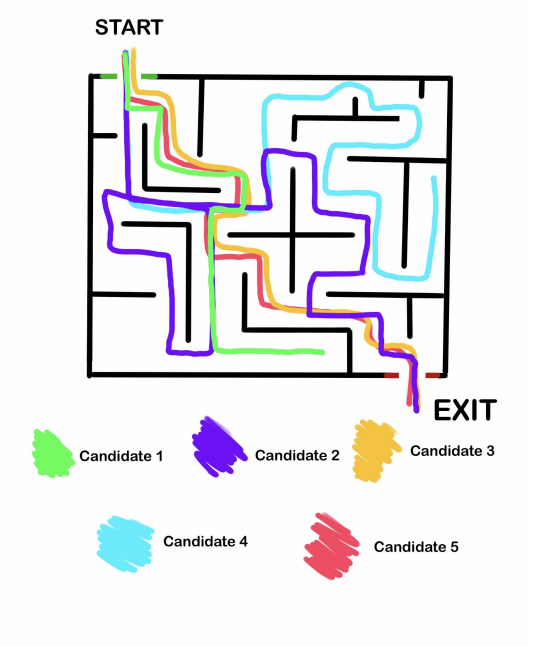

Figure 1: Shows a cognitive map that represents a test conducted on 5 individuals and their progression through a simple maze. 3 of which made it to the end and the other 2 failed.

The aim of the experiment were to train the rats to go a certain path to acquire a food package. Then, when the rats memorised the path, they would change the scenario in a way that corresponds to the previous layout but blocks off some of the original paths. Not only this, the end goal had been lit with a lamp to act as a beacon to give the rats a sense of direction. After the experiment concluded, it was recorded that only 36 percent of the test subjects subconsciously went towards the familiar path and couldn't acquire the food. Which didn't really prove the theory of metric cognitive mapping, but instead showed more signs of stimulus response learning.

A similar experiment was later conducted in humans and had proved that humans possess the ability to point out key features of familiar or previously traversed terrain. Though, it is rather an estimate and does have a tendency to be incorrect. As there is a bracket of **20-100 deg** in which the person could potentially deviate from their path. Resulting in the person unintentionally missing their end goal.

3.2 Stencil Shader Buffers

Stencil Buffering is a technique used to create a mask on an object that will completely disregard pixels and only show what is necessary. The stencil can be used as an alpha mask on the face of a shape. The example given on the web page [1] describes it being similar to looking through a window and seeing a mountainscape. What it does it is basically hides everything that is outside the view of the window by the marking pixels between the frame with an arbitrary value of 1. This value will be used to signify that anything marked with the value of 1 within the frame will be kept and anything else will be disregarded.

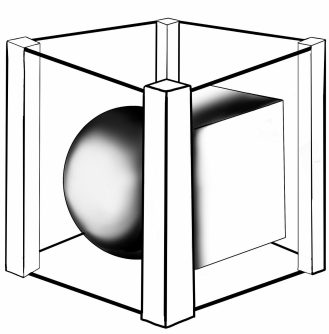

Figure 2: A visual representation of a Stencil Buffer working on a cube object.

With the artefact being created in the Unity Game Engine, looking for implementation techniques is actually rather simple as Unity comes with a plethora of documentations that help in achieving multiple different effects. The one document that will be focused on is heavily is the **ShaderLabs: Stencil** [3]. This is due to the fact that it explains what procedures need to be taken in order to get the desired effect.

4 Artefact

4.1 What is going to be created?

The intended artefact that I'm creating will consist of a linear-esque level design where the player is tasked to pick up an object and place it onto a button at another point within the level. However, the more the player progresses through each of the levels, the more Non-Euclidean elements are revealed with the intent on slowing their progression.

Some of the Non-Euclidean aspects I intend on developing will have near similarities to the method in which the **Portal** games use their seamless transitions through each of the portals. However instead of creating a small surface that the player can see visually, I intend on having these transitions placed

within the game's environment at all times that will not be noticeable until the player has a moment of realisation. This can be done within Unity rather simply. As it uses two separate cameras (let's say cameras **A** and **B**) and places them so they are looking towards a screen at two separate points within the level. Both of these cameras will orbit their screen as they essentially replicate the player's camera movements. Camera **A** will project the perspective of camera **B** onto a screen that is situated with **A** to get the image of the opposite side. As the player moves and looks through the screen, they should see the current perspective of camera **B**.

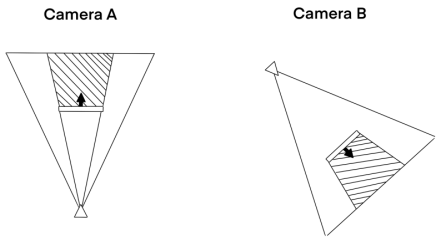

Figure 3: Shows the positions of cameras A and B.

Using this method of simple camera trickery will allow me to replicate the idea of looping corridors, infinitely ascending/descending staircases, portals and much more.

To be able to get a thorough test that works as intended, I'll need to use the Non-Euclidean formula, or as it is better known as the **Hyperbolic Geometry** formula, which can be viewed here [5].

4.2 How is it going to be created?

I aim to use the Agile methodology closely as I going to ensure a consistent level of work is being completed over the duration of a 16 week period. This allows for a game level to be created every 2 weeks as part of a sprint plan I'm devising. Furthermore, within this time I will be running QA tests frequently to ensure that the Non-Euclidean geometry is working as intended.

4.3 Test Plan

I aim for my experiment to take these feelings of confusion to test a user's efficiency within a simple navigational task. I will begin the experiment by handing them a questionnaire which will ask if they've ever had any experience with games before and to see their overall experience with games. Then after they've finished the questionnaire and the task has been completed, I'll hand them a second questionnaire which will ask how they found the experiment. On completion, they will then be asked to go through a different version of the same level but with more Non-Euclidean elements and then complete a third questionnaire. Again, asking how they found the test.

5 Research Methodology Acknowledgements

5.1 Data Collection

To gather the data needed for this experiment, the aforementioned questionnaire will be the primary source of this research as I have tailored all of the questions to be relevant towards my hypotheses. I have not included anything that is personal to the participants as the research does not require them.

5.2 Storing Collected Data

The data will be stored within a simple Excel spreadsheet document as it keeps everything together and makes it easier to calculate the percentages when the experiment has concluded.

5.3 Ethical Considerations

With the experiment being a psychological test and the safety of the participants and faculty being the most high priority. I have taken consideration of numerous risks and have thought of ways that can reduce the level of likely-hood towards both parties. The following subsections will address these and explain how they will be followed within the experiment.

5.3.1 Nausea and Anxiety

With the experiment dealing with the disorientation of participants and how they process the Non-Euclidean elements. My main worry is that the candidate may be prone to nausea and the test might induce anxiety. I aim to alleviate some of these feelings by giving the participant an in depth explanation on Non-Euclidean geometry beforehand and allow for them to leave if they do not feel comfortable with participating.

5.3.2 Illness Associated with Consistent Computer Use

A common form of illness that may occur when using a computer for an extended period of time is either RSI or eye straining. Either of which are deemed a main cause for concern when conducting the experiment as eye straining can lead to visual impairment and high levels of pain where as RSI may possibly lead to a posture deformity. I hope to alleviate this by giving the candidate a brief moment to take a break in which they can recuperate themselves and come back to the test and continue. Another cause for concern is the matter of headaches or migraines. To combat this, I'm allowing for the candidate to withdraw from the experiment if they are starting to feel these such sensations. A member of staff will also be around if they require any immediate help.

5.3.3 Withdrawal from the Experiment

As mentioned previously, the candidate is free to leave the experiment at anytime without consequence if they feel uncomfortable at anytime during the study.

5.3.4 Covid-19 Saftey

Covid-19 is still being considered a threat at the current moment. Precautionary measures will be taken very seriously when running the experiment to avoid any infections towards the candidates and those in close proximity to the research station. So to make sure everything runs perfectly:
- Face coverings must be worn at all times;
- A risk assessment of the equipment will be completed;
- Social distancing will be enforced before anything proceeds;
- The equipment will be sanitised after every use.

6 GitHub Repository

https://github.com/Lieu-Tennie/Non-Euclidean-Virtual-Environment-Artefact

References

[1] David Gavilan. *The Stencil Buffer and how to use it to visualize volume intersections.* URL: https://tech.metail.com/the-stencil-buffer-and-how-to-use-it-to-visualize-volume-intersections/. (accessed: 14.12.2020).

[2] A. Glassner. "Going the distance [2D geometry]". In: *IEEE Computer Graphics and Applications* 17.1 (1997), pp. 78–84. DOI: 10.1109/38.576861.

[3] Unity. *ShaderLab: Stencil.* URL: https://docs.unity3d.com/Manual/SL-Stencil.html. (accessed: 14.12.2020).

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[5] Eric W. Weisstein. *Hyperbolic Geometry.* URL: https://mathworld.wolfram.com/HyperbolicGeometry.html. (accessed: 10.12.2020).