Mapping hyperbolic space for the virtual reality game "Holonomy"

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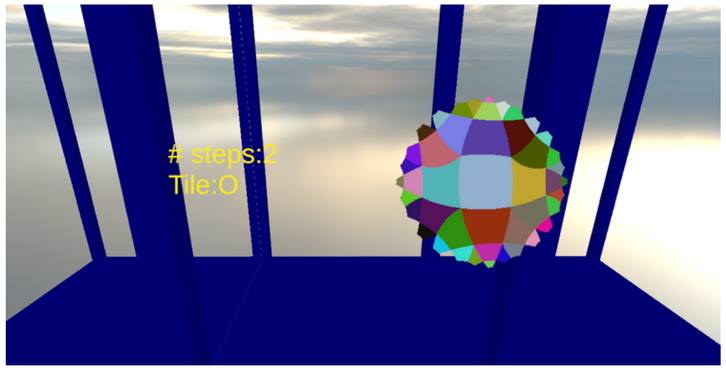

Figure 1: Screenshot of "Holonomy" in Non-VR scene with old map

1) Introduction

- VR game (called "Holonomy") in 3x3m real world space, floor of the game world is hyperbolic
- VR game tries to illustrate Holonomy
- Figures 1 and 2 should give more of an idea

- Old implementation is too complex and not easy to extend with new features
- Old implementation is also too slow for continuous rendering of the world
- Map uses the Poincaré disk model
- Maps for hyperbolic space are difficult since size of tiles gets distorted

2) Research question

What is a simple and fast algorithm to render the hyperbolic plane and is suitable for the VR game "Holonomy"?

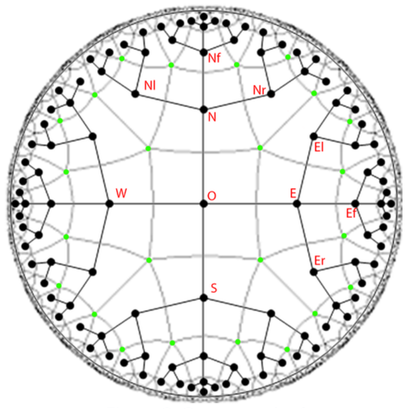

Figure 3: Game graph of "Holonomy" (Image credit to Scott Jochems)

	MI	CC	CO	LOSC	LOEC
Circle	67	7	4	62	29
Direction	91	1	0	13	2
DirectionUtils	80	10	2	39	4
Geodesic	65	12	4	81	20
GeomUtils	63	16	4	200	76
HolonomyTile	69	18	19	182	37
HolonomyTiling	66	25	18	192	73
MainForm	72	14	23	117	38
Step	91	1	0	11	2
Mean	73.8	11.6	8.2		
Weighted mean	67.0	16.8	12.1		
Standard deviation	10.3	7.4	8.5		
Sum				897	281
Old minimap	58	33	42	314	162

Table 1: Code metrics for new minimap against old minimap. MI=Maintainability index, CC= Cyclomatic complexity, CO=Class coupling, LOSC = Lines of source code, LOEC=Lines of executable code. Weighed mean is based on fraction of LOEC

3) Method

- Can generate Euclidean tiling by drawing an origin tile, then reflecting that along its edges
- Again, we use the Poincaré disk model
- Tiling works similar in the Poincaré disk. Just need to concern ourselves with constructing an origin tile.
- Lines in the Poincaré disk are just circles [1]
- Circle inversion: OA*OA' = r^2 [2]
- To reflect, invert points in edges of tile
- Use the game graph (Figure 3) to not construct duplicate tiles
- Tiling translation: construct a hyperbolic middle line between origin of unit circle and new point. (Figure 5)

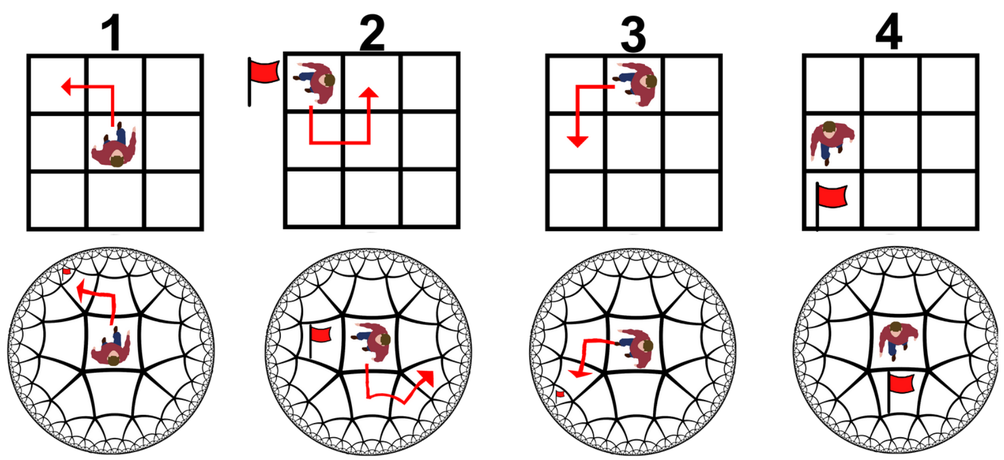

Figure 2: How hyperbolic geometry works in "Holonomy" (Image credit to Joris Rijsdijk)

	Old minimap	New minimap
Runtime of 10 different executions	17, 17, 19, 18, 19, 18, 19, 17, 17, 18	25, 27, 26, 25, 26, 25, 25, 25, 27, 25
Standard deviation	0.83	0.80
Mean	17.9	25.6

Table 2: Speed comparison of old against new minimap in milliseconds

4) Evaluation

- New minimap is a more faithful representation of hyperbolic space
- Code metrics computed for old and new minimaps. Both minimaps written in C#
- Lower cyclomatic complexity and coupling
- Slightly higher Maintainability index
- In general: new implementation is more organized. Thus, easier to extend.
- New minimap is slightly slower, it does not use a compute shader.
- Some minimap generation behaviour is not completely correct

5) Conclusions & Future work

- New minimap generation draws game world more faithfully than the old implementation
- New minimap is simpler and easier to extend with other features
- New minimap is slower, leaving significant possibilities for future work
- Further research in navigation: non-continuous map vs continuous map in user tests

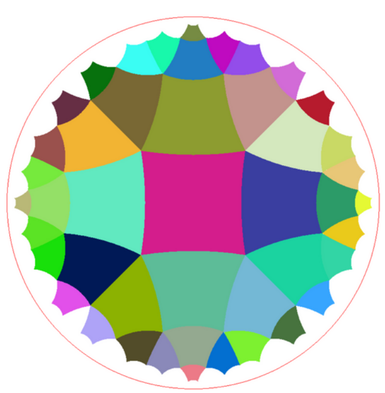

Figure 4: New rendering of the minimap (for 45 tiles)

Figure 5: Translated minimap

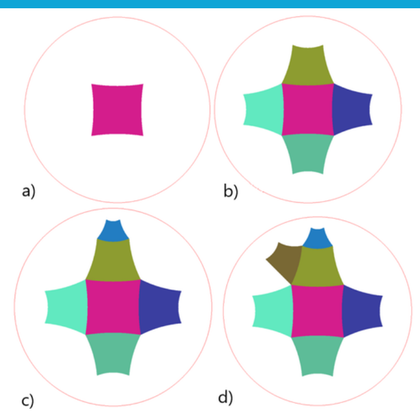

Figure 6 New minimap generation process

[1] GOODMAN-STRAUSS, CHAIM. “Compass and Straightedge in the Poincaré Disk”. The American Mathematical Monthly 108.1 (2001). Publisher: Mathematical Association of America, 38–49. ISSN: 0002-9890. DOI: 10 . 2307 / 2695674. URL: https : / / www . jstor .org/stable/2695674
[2] COXETER, H. S. M. “Inversive Geometry”. Educational Studiesin Mathematics 3.3 (1971).Publisher: Springer, 310–321. ISSN: 0013-1954. URL: https://www.jstor.org/stable/3482030