Notes on Permadi Raycasting Tutorial

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Disclaimer: For the first part (where I implemented along the Permadi tutorial chapters) the notes are pretty decent and structured. The second part (where I experimented with additional concepts in ray casting) the notes are not very structured (yet).

The Permadi tutorial series (explanation and examples) can be found here:
https://permadi.com/1996/05/ray-casting-tutorial-table-of-contents/
All my implementations using the PixelGameEngine can be found on my github:
https://github.com/Joseph21-6147/Raycasting-tutorial-series---Permadi-inspired

If you want to code along, you'll need to provide the sprite and texture files yourself.

*Advice: The notes do not provide a complete description of the implementations. There are several sources you **should** combine with these notes to get the complete picture:*

1. *The Permadi tutorial pages;*
2. *The differences between the current code file you are studying and the previous – use some difference analyzer like WinMerge to get the incremental changes in the code visible.*
3. *Each code file has its own header comment in which I summarize what is changed with respect to the previous code file.*
4. *I try to make the code readable by adding comments where appropriate. So in the end you'll just have to read code* 😊

Preface

- Tutorial notes[1] - none
- Implementation notes[2] - none

Part 1 – Introduction

- Tutorial notes
  - Describes the history and the concept of ray casting
- Implementation notes - none

Part 2 – Ray casting vs Ray tracing

- Tutorial notes - none
- Implementation notes - none

[1] The tutorial notes refer to the Permadi tutorial

[2] The implementation notes refer to my implementation code files. As you can see upto part 9 of Permadi tutorial there are no implementations (yet), since it's all history, background and theory

Part 3 – Limitations of ray casting

- Tutorial notes
  - relevant theory starts here
- Implementation notes
  - each tile is split in 64x64 units, and each cube in 64^3 units. I'm struggling how to model this, since keeping the tiles as units (like Javid does) is much more logical for the ray tracing. For now I only created some int nTileSize and nGridX, nGridY pair that are derived from nTileSize in combination with nMapX, nMapY. However, these variables aren't used anywhere (yet)[3]
  - I created a map (modeled as a string), defined a map size

Part 4 – Step 2 = Defining projection attributes, part 5

- Tutorial notes - none
- Implementation notes
  - I created class variables for the player position, it's viewing angle, its field of view and its height.
  - The viewing angle and field of view is in degrees

Part 6 – step 3 = Finding Walls, part 7

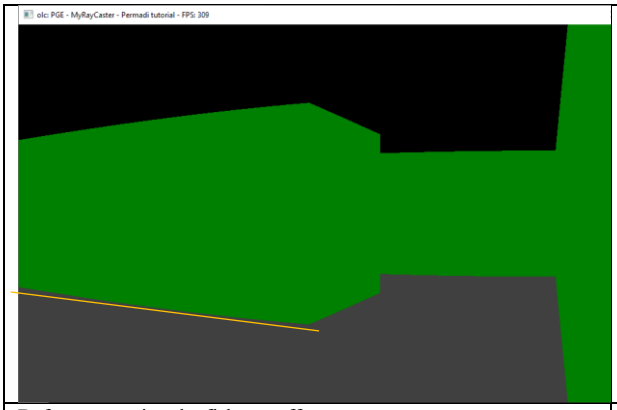
- Tutorial notes
  - this is where the Differential Data Analysis (DDA) algorithm comes in. Imo the explanation in the Permadi tutorial isn't particularly comprehensive, so I sought and found more explanation in for instance Javid's video on DDA[4].
- Implementation notes
  - I adopted the DDA algo code from javid's video tutorial, and wrapped it in a function to use it in this tutorial
  - Later on I implemented my own DDA function, based on Javid's video. So I adopted the idea and the concept of the algorithm, but didn't copy the code.

Part 8 – step 4 = finding distance to walls

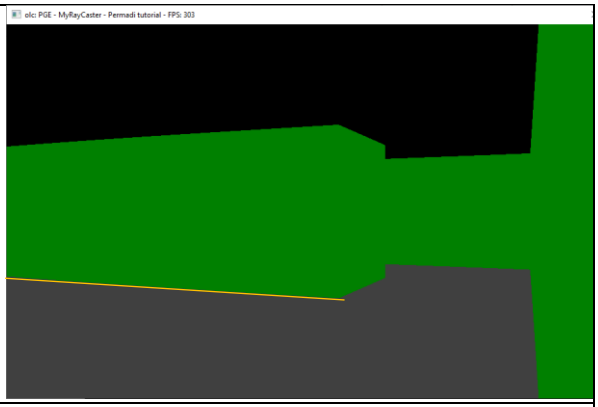
- Tutorial notes
  - Describes the fish eye effect and a way to correct that
- Implementation notes
  - This correction uses an additional cosf() call. This is only needed per screen slice. I might optimize performance using a lookup table in the future.

[3] Later I removed this code. My map / wall blocks are 1 x 1 x 1 in size. The initial height of the player is 0.5f

[4] See: https://www.youtube.com/watch?v=NbSee-XM7WA&t=1053s&pp=ygULamF2aWR4OSBkZGE%3D



Before correcting the fish eye effect…



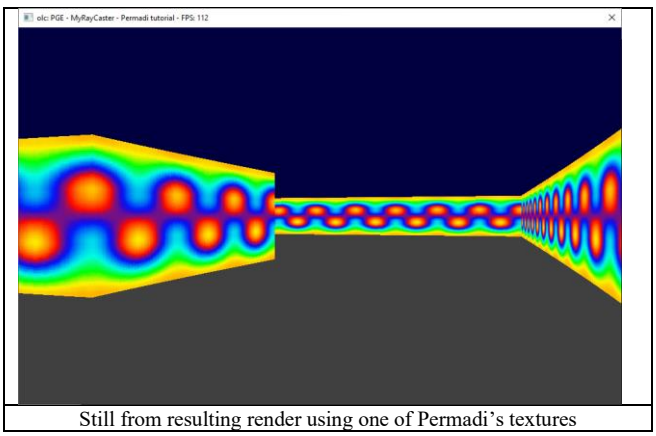
… and after – the yellow line is added to the rendered image to check on straightness of the walls

Part 9 – step 5 = Drawing walls

- Tutorial notes
  - In the tutorial a constant number of 277 is presented as the distance to the projection plane. This number is a result of the (choice of the) screen width (320 in the tutorial) in combination with the field of view angle (60 degrees, the cos of half of that is ½ √3 == 0.866, so 320 * 0.866 == 277 (rounded oc)).
- Implementation notes
  - I implemented this distance to the projection plane as a derivation instead of a constant: Since the screen width and the field of view don't change during the game, this calculation is put in OnUserCreate()
  - [saved a copy of the source file – since I finally got the code rendering something]
  - [saved an alternative of the source file using the DDA algorithm instead of ray marching]
  - [saved an alternative with a simple form of shading of the monochrome walls]

Part 10 – Textured mapped walls

- Tutorial notes
  - None
- Implementation notes
  - Needed some debugging time to find out I missed a '&' in the parameter to GetDistanceToWall(). The y coordinate of the cell wasn't interpreted as a reference and didn't get any value due to this… Now it's working fine:



Still from resulting render using one of Permadi's textures

- I downloaded Permadi's texture files in the process. Not particularly special (and only 64x64 resolution), but handy (and colourful).
- [saved a copy of the source file]

Part 11 – Drawing floors & Part 12 – Floor casting (continued)

- Tutorial notes
  - The way of thinking from the tutorial is pretty clear: the theory is comprehensible. You have to add a lot of your own stuff to get it implemented. The tutorial describes how to get the floor distance, and then you have to implement yourself how to work that out to the correct floor location (tile), and to the correct sample coordinates for sampling the floor sprite.
- Implementation notes
  - Success!! [although it takes a performance hit with 1 x 1 pixelsize 😊]
  - It's just the right amount of challenge. Not too easy, you got to figure things out for yourself.

Successfully textured floor

Part 13 – Drawing ceilings

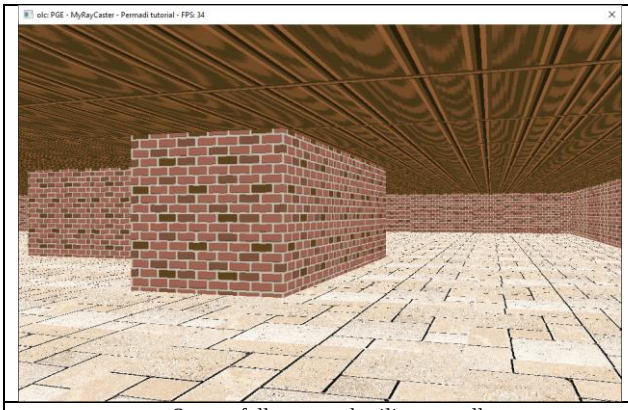
- Tutorial notes
  - This is a straightforward extension of part 11 and 12
- Implementation notes
  - Texturing the ceilings is a pretty straightforward variation on texturing the floors. You only have to take into account the relation of the y screen coordinate and the middle of the screen height…
  - For the floor:

```
// work out the distance to the location on the floor you are looking at through this pixel
// (the pixel is given since you know the x and y to draw to)
float fFloorProjDistance = ((fPlayerH / float( y - nHalfScreenHeight )) * fDistToProjPlane)
                                / cos( fViewAngle * PI / 180.0f );
```

  - For the ceiling:

```
// work out the distance to the location on the ceiling you are looking at through this pixel
// (the pixel is given since you know the x and y screen coordinate to draw to)
float fCeilProjDistance = ((fPlayerH / float( nHalfScreenHeight - y )) * fDistToProjPlane)
                                / cos( fViewAngle * PI / 180.0f );
```

  - Success!!



Successfully textured ceiling as well

Intermezzo:

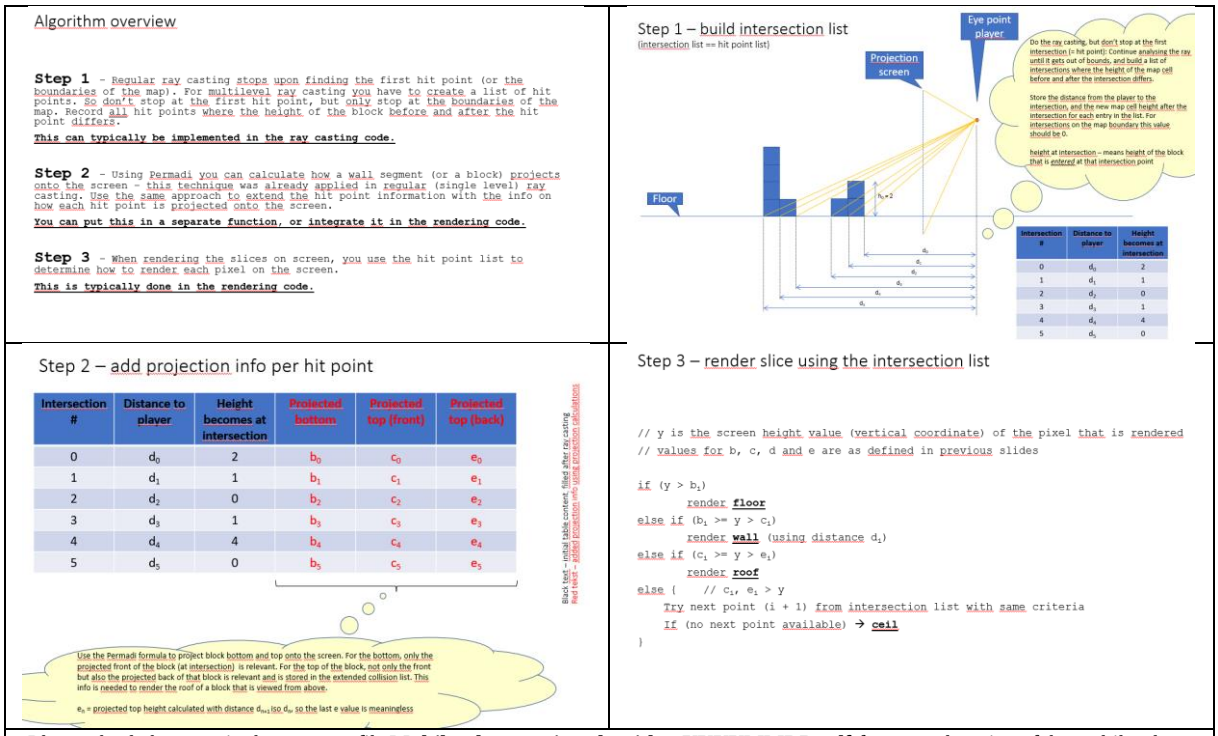
1. Got a reference from discord to: https://lodev.org/cgtutor/raycasting.html Check it out, looks usable. Javid refers to this site as well in his DDA video.
2. Performance is taking a hit since I use a lot of trig functions:
    a. One atan2f() call for each wall pixel;
    b. One sin() and one cos() call for each floor and each ceiling pixel;

   I can try to optimize with sin() and cos() as lookup values rather than function calls.

Part 14 – Variable height walls

- Tutorial notes
    - The explanation in the Permadi tutorial is not straightforward (for me at least). So I pretty much derived my own approach on this challenge. Refer to the separate file **Multilevel raycasting algorithm YYYYMMDD.pdf** for the explanation of this algorithm.
- Implementation notes
    - The DDA function that determines the first hit and the distance and location thereof had to be adapted to return a list of hits for each map cell that has a height > 0. This list of hits is used in the rendering of walls.
    - Permadi's tutorial really wasn't that helpful for this topic. It took me a lot of time to figure this out…
        - First step was to enhance the function that calculates the distance to the nearest wall: it should return a list of all walls that are intersected (not just the first one), including their heights.
        - Second step is to build up each vertical line on the screen using that info. If a wall is hit, render it, else render either floor or ceiling. If another wall is behind the first one, and is heigher, render the top part[5].

[5] I experimented with multi level raycasting in the past, as an extension of Javidx9's video's. The approach I followed in this Permadi tutorial is very similar to what I worked out before I followed the permadi tutorial.



Please check the notes in the separate file **Multilevel raycasting algorithm YYYYMMDD.pdf** *for an explanation of the multilevel ray casting algo*

Part 15 – Horizontal movement

- Tutorial notes
  - If you are familiar with Javidx9's video's on first person shooter, this stuff is explored territory. If you're not, check them out.[6]
- Implementation notes
  - I implemented these movements already in the first version of the code (the implementation of part 9), since there wouldn't be much to look at or to test otherwise… So the implementation is already done at the start (part 9).
  - Besides rotation and forward and backward movement, I also implemented strafing left and right.
  - Experimented and defined movement speeds for rotation, strafing and forward / backward.

Part 16 – Vertical Motion: looking up and down

- Tutorial notes
  - This is a feature that Javidx9 didn't explain.
- Implementation notes
  - This is quite trivial to implement. I added a class variable fLookUp, which is 0.0f initially, and which is controllable with the up and down arrow keys. Although it expresses pixels (screen space), the variable must be a float to fractionally (i.e. smoothly) increase or decrease the value. I let the value of the vertical half of the screen depend on it:

[6] See youtube: https://www.youtube.com/watch?v=xW8skO7MFYw&t=1001s&pp=ygULamF2aWR4OSBmcHM%3D and https://www.youtube.com/watch?v=HEb2akswCcw&t=1820s&pp=ygULamF2aWR4OSBmcHM%3D

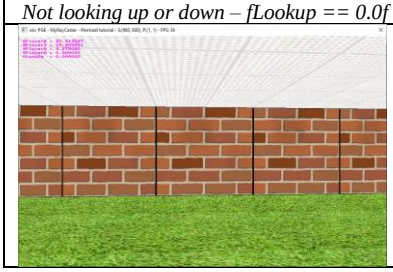
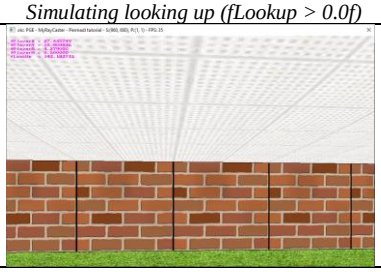
```
int nHalfScreenWidth  = ScreenWidth()  / 2;

int nHalfScreenHeight = ScreenHeight() / 2 + (int)fLookUp;
```

- This is where that value is applied:

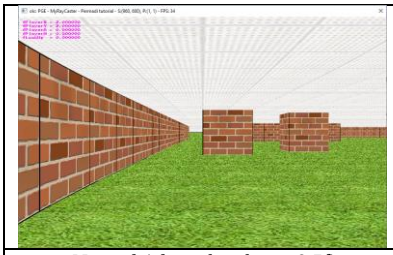
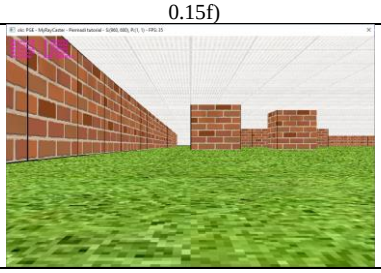
Code file / line / code	What happens there?
main.cpp|418|int nHalfScreenHeight = ScreenHeight() / 2 + (int)fLookUp	Calculation of value
main.cpp|435|float fCeilProjDistance = ((fPlayerH / float(nHalfScreenHeight - py)) * fDistToProjPlane) / cos(fViewAngle * PI / 180.0f)	Sampling of the ceiling
main.cpp|450|float fFloorProjDistance = ((fPlayerH / float(py - nHalfScreenHeight)) * fDistToProjPlane) / cos(fViewAngle * PI / 180.0f)	Sampling of the floor
main.cpp|481|nWallCeil = nHalfScreenHeight	Default value if no wall
main.cpp|482|nWallFloor = nHalfScreenHeight	Default value if no wall

- The results are identical to Permadi's example illustrations[7]:

Not looking up or down – fLookup == 0.0f	*Simulating looking up (fLookup > 0.0f)*	*Simulating looking down (fLookup < 0.0f)*
		

Part 17 – Vertical Motion: flying and crouching

- Tutorial notes
  - This is a feature that Javidx9 didn't explain in his FPS series.
- Implementation notes
  - For a single layer (non multilevel walls) environment, I got it working after quite some experimentation:

		
Normal (player height == 0.5f)	Simulating crouching (player height == 0.15f)	Simulating flying (player height == 0.85f)
		
	Adapted lookup value	Player height 0.9f, adapted lookup value

  - Note that the horizon is shifting due to changing the player height. If you don't want this, you can compensate for this, by adapting the look up value. This is what is done in the second row of illustrations above. After these experiments I built this into the code to compensate for height changes of the horizon by altering the fLookUp value.
  - So for simple single level maps this works fine, and the player height is even clamped within the open range <0.0f, 1.0f>.

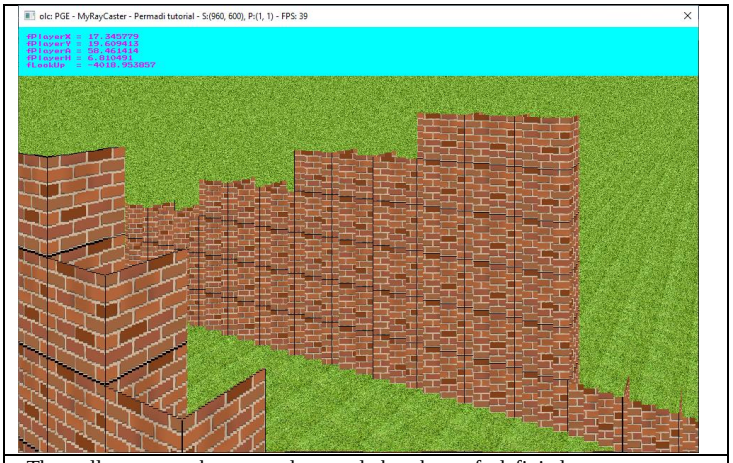
[7] I googled a couple of sprites to really resemble the Permadi example 😊

- For multilevel maps the flying and crouching works correctly, but the rendering is not sufficient. I already made some corrections to check for the horizon height:

```
                if (y >= nWallFloor) {
//                    nDrawMode = FLOOR_DRAWING;
                    nDrawMode = (y <= nHorizonHeight) ? CEIL_DRAWING : FLOOR_DRAWING;
                } else …

                        } else {
//                          nDrawMode = CEIL_DRAWING;
                            nDrawMode = (y <= nHorizonHeight) ? CEIL_DRAWING : FLOOR_DRAWING;
                        }
```

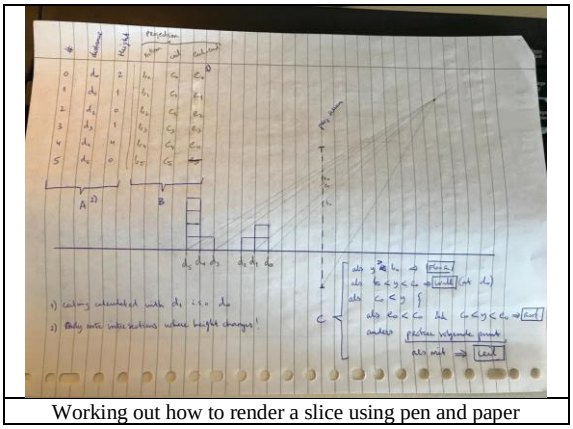
After implementing flying and crouching I found that the roofing (the top faces) of the wall blocks isn't correctly rendered yet:



The walls appear to be textured correctly but the roofs definitely are not correct

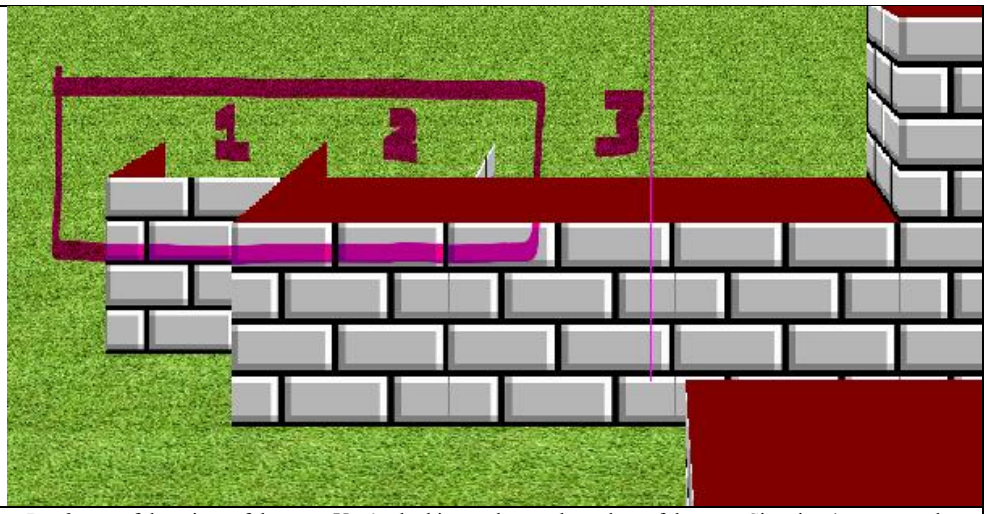
See hand written notes below. I created an algorithm where

A. The adapted DDA function generates a complete list of all the raster points where the height of the heightmap differs (before I simply took the raster points where the height was > 0);
B. After the list is composed along the ray, it is extended with the projected heights of bottom, ceiling and possibly back-ceiling (in order to render roofs).
C. This info is used to render floor, wall, roof and/or ceiling per slice.

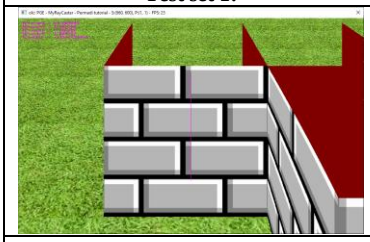
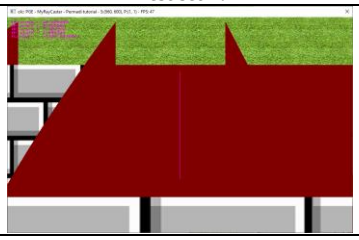
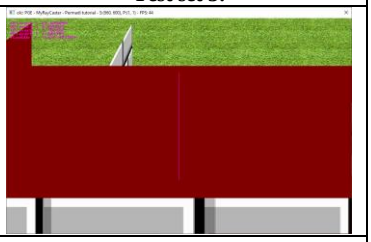


Working out how to render a slice using pen and paper

This works OK, but not at the boundaries of the map. Something's going wrong there…

<table>
<tr>
<td> 
</td>
<td> 
</td>
</tr>
<tr>
<td>Map detail: ‘.’ = height 0, ‘#’ = height 1</td>
<td>Rendering of that piece of the map. You’re looking at the east boundary of the map. Situation 1 corresponds with map location (31, 1), situation 2 with (31, 2) etc</td>
</tr>
</table>

Situation 3 is rendered as expected, but situations 1 and 2 are not. What’s happening here?

<table>
<tr><th>Test set 1:</th><th>Test set 2:</th><th>Test set 3:</th></tr>
<tr>
<td>  </td>
<td>  </td>
<td>  </td>
</tr>
<tr><td colspan="3">I wrote some test code that prints (upon pressing T) the intersection list at the slice denoted by the magenta line</td></tr>
</table>

Output of intersection lists:

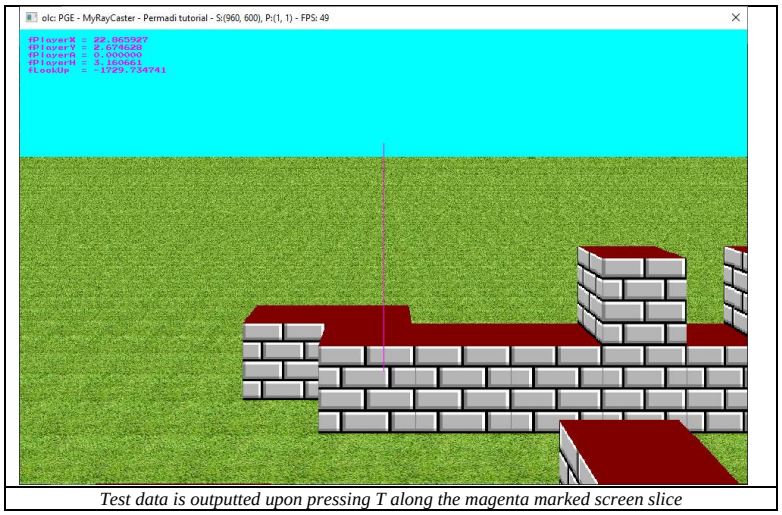
```
// Test set 1 intersection list:
fIntersectX: 31, fIntersectY: 1.5355 , nMapCheckX: 31, nMapCheckY: 1, fDistance: 1.97075 , nHeight: 1, bottom_front:  553, ceil_front: 132, ceil_back: 132
fIntersectX: 31, fIntersectY: 1.5355 , nMapCheckX: 31, nMapCheckY: 1, fDistance: 1.97075 , nHeight: 0, bottom_front:  553, ceil_front: 553, ceil_back: 553

// Test set 2 intersection list:
fIntersectX: 30, fIntersectY: 2.58958, nMapCheckX: 30, nMapCheckY: 2, fDistance: 0.970755, nHeight: 1, bottom_front: 1356, ceil_front: 500, ceil_back: 132
fIntersectX: 31, fIntersectY: 2.58958, nMapCheckX: 31, nMapCheckY: 2, fDistance: 1.97075 , nHeight: 0, bottom_front:  553, ceil_front: 553, ceil_back: 553

// Test set 3 intersection list:
fIntersectX: 30, fIntersectY: 3.42653, nMapCheckX: 30, nMapCheckY: 3, fDistance: 0.970755, nHeight: 1, bottom_front: 1356, ceil_front: 500, ceil_back: 132
fIntersectX: 31, fIntersectY: 3.42653, nMapCheckX: 31, nMapCheckY: 3, fDistance: 1.97075 , nHeight: 0, bottom_front:  553, ceil_front: 553, ceil_back: 553
fIntersectX: 31, fIntersectY: 3.42653, nMapCheckX: 31, nMapCheckY: 3, fDistance: 1.97075 , nHeight: 0, bottom_front:  553, ceil_front: 553, ceil_back: 553
```

Observations:

- The fDistance value of the last point is not correct: because the cached version of the distance was stored into the list, the distance to the back of the cell was reported identical to the distance to the front of the cell. I fixed this and the rendering problem was solved instantly 😊
- For situations where a cell doesn’t cross the boundary, an additional entry is created in the list. This is not needed, but it’s not harmful for the rendering, so I leave it as it is. → later I used a more clever condition, that an additional entry is only inserted if the list is not empty and the current height > 0. This prevents the unnecessary insertion of additional nodes.



Test data is outputted upon pressing T along the magenta marked screen slice

Output after the fix of the same three test sets of intersection lists:

```
// Test set 1 intersection list:
fIntersectX: 23, fIntersectY: 1.7184, nMapCheckX: 23, nMapCheckY: 1, fDistance: 0.134073, nHeight: 1, bottom_front: 19763, ceil_front: 13563, ceil_back: 601
fIntersectX: 27, fIntersectY: 1.7184, nMapCheckX: 27, nMapCheckY: 1, fDistance: 4.13407, nHeight: 0, bottom_front: 802, ceil_front: 802, ceil_back: 489
fIntersectX: 31, fIntersectY: 1.7184, nMapCheckX: 31, nMapCheckY: 1, fDistance: 8.13407, nHeight: 1, bottom_front: 489, ceil_front: 387, ceil_back: 363
fIntersectX: 31, fIntersectY: 1.7184, nMapCheckX: 31, nMapCheckY: 1, fDistance: 9.13407, nHeight: 0, bottom_front: 454, ceil_front: 454, ceil_back: 454

// Test set 2 intersection list:
fIntersectX: 30, fIntersectY: 2.62545, nMapCheckX: 30, nMapCheckY: 2, fDistance: 7.13407, nHeight: 1, bottom_front: 533, ceil_front: 417, ceil_back: 363
fIntersectX: 31, fIntersectY: 2.62545, nMapCheckX: 31, nMapCheckY: 2, fDistance: 9.13407, nHeight: 0, bottom_front: 454, ceil_front: 454, ceil_back: 454

// Test set 3 intersection list:
fIntersectX: 30, fIntersectY: 3.2822, nMapCheckX: 30, nMapCheckY: 3, fDistance: 7.13407, nHeight: 1, bottom_front: 533, ceil_front: 417, ceil_back: 387
fIntersectX: 31, fIntersectY: 3.2822, nMapCheckX: 31, nMapCheckY: 3, fDistance: 8.13407, nHeight: 0, bottom_front: 489, ceil_front: 489, ceil_back: 454
fIntersectX: 31, fIntersectY: 3.2822, nMapCheckX: 31, nMapCheckY: 3, fDistance: 9.13407, nHeight: 0, bottom_front: 454, ceil_front: 454, ceil_back: 454
```

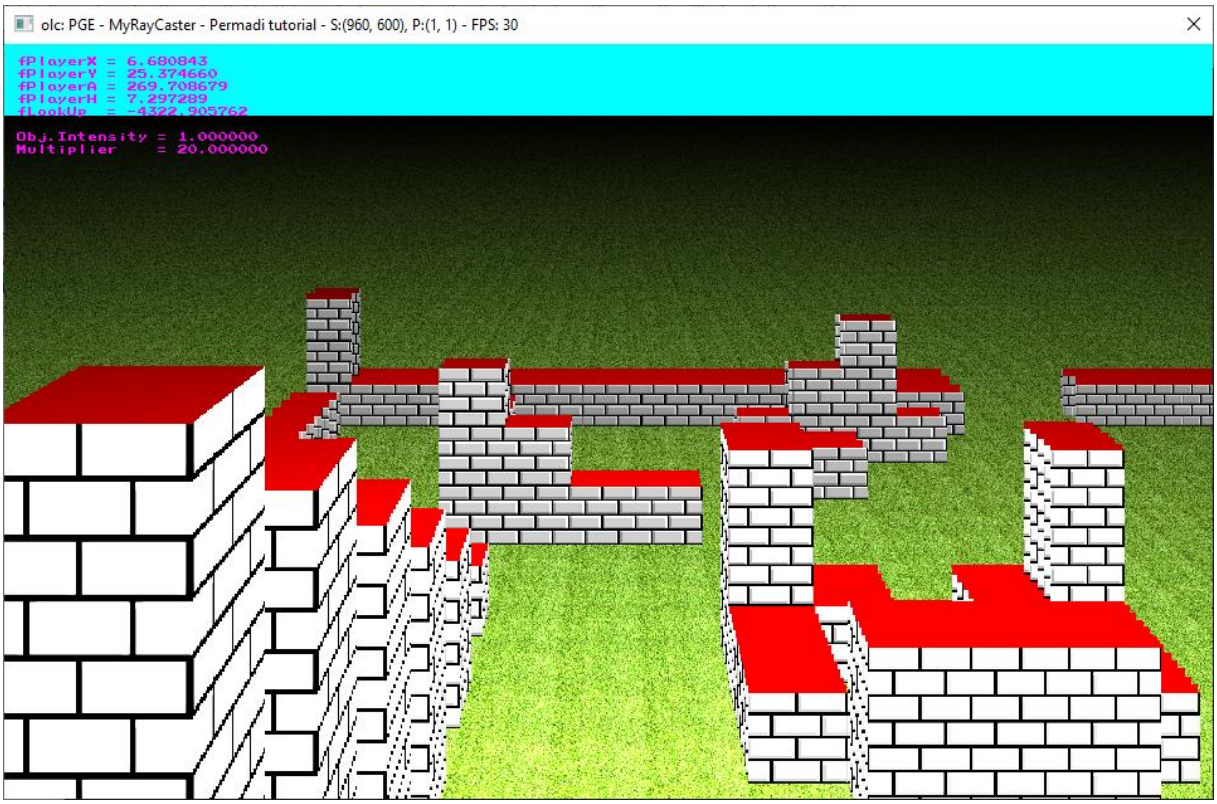
Saved a copy of the working code including test code.

Part 18 – Vertical Motion: combined effects

- Tutorial notes
  - The theory brings nothing new, it's just combining what was already achieved from earlier parts
- Implementation notes
  - I already implemented this. Flying and crouching is controlled with page up resp. page down. Looking up and down is controlled with arrow up resp. down key. Flying and crouching is done with built in functionality to keep the horizon at a constant level (by adapting the looking up and down angle).
  - So all these combined effects are implemented in part 17 already.

Part 19 – Shading

- Tutorial notes
  - Simple description on colour theory, and a formula to use for fast shading
- Implementation notes
  - Example shading:



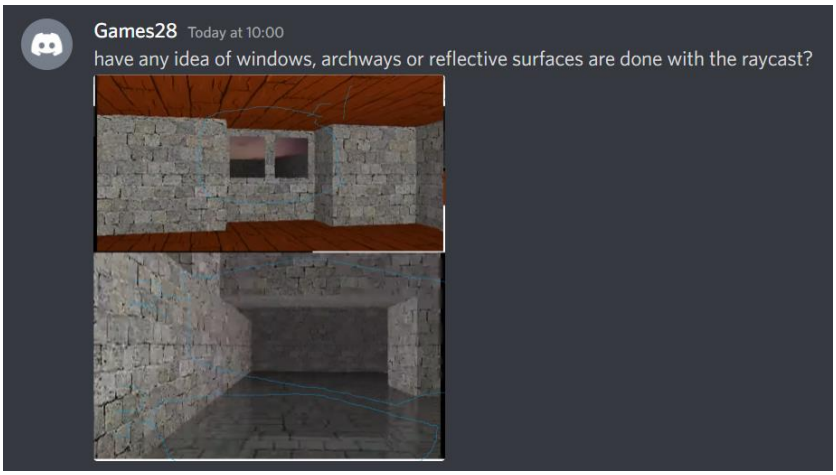
- I found that the background was too dark where the foreground was too light. Solved this by clamping the shading factor between two values (e.g. [0.1f, 1.0f]).

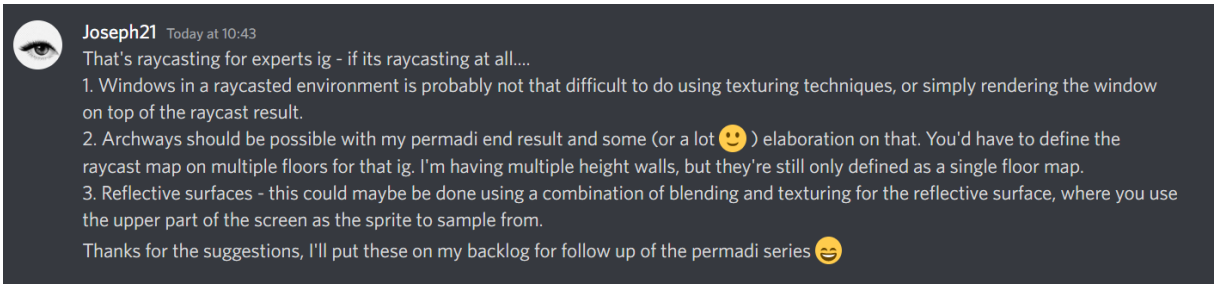
Still to do:

1. There's some nasty bug with the rendering on the boundaries of the map that I have to sort out.	solved, see notes on part 17
2. According to the tutorial there's only shading to cover. I want to do some experimenting with that as well.	done, see notes on part 19
3. For now I've only done textured ceilings with single level maps. I'm planning on trying to get textured ceilings to work in combination with multiple level maps.	NOTE: looking forward this is implemented in parts 22a-22d
4. And I want the texturing to be more flexible, so i'm looking for a way to give each face of each block its own texture (Sprite *).	NOTE: looking forward this is implemented in parts 23b-23c
5. Want to improve the DDA algorithm still, and see if I can get some performance improvements going - multilevel rendering takes a lot of processing power...	Done, don't believe there's much possible still
6. Add billboard rendering for objects and actors in my ray cast world…	NOTE: looking forward this is implemented in part 23a

I think I'm gonna code other stuff than ray casting for a while…

Note 2022-06-07:

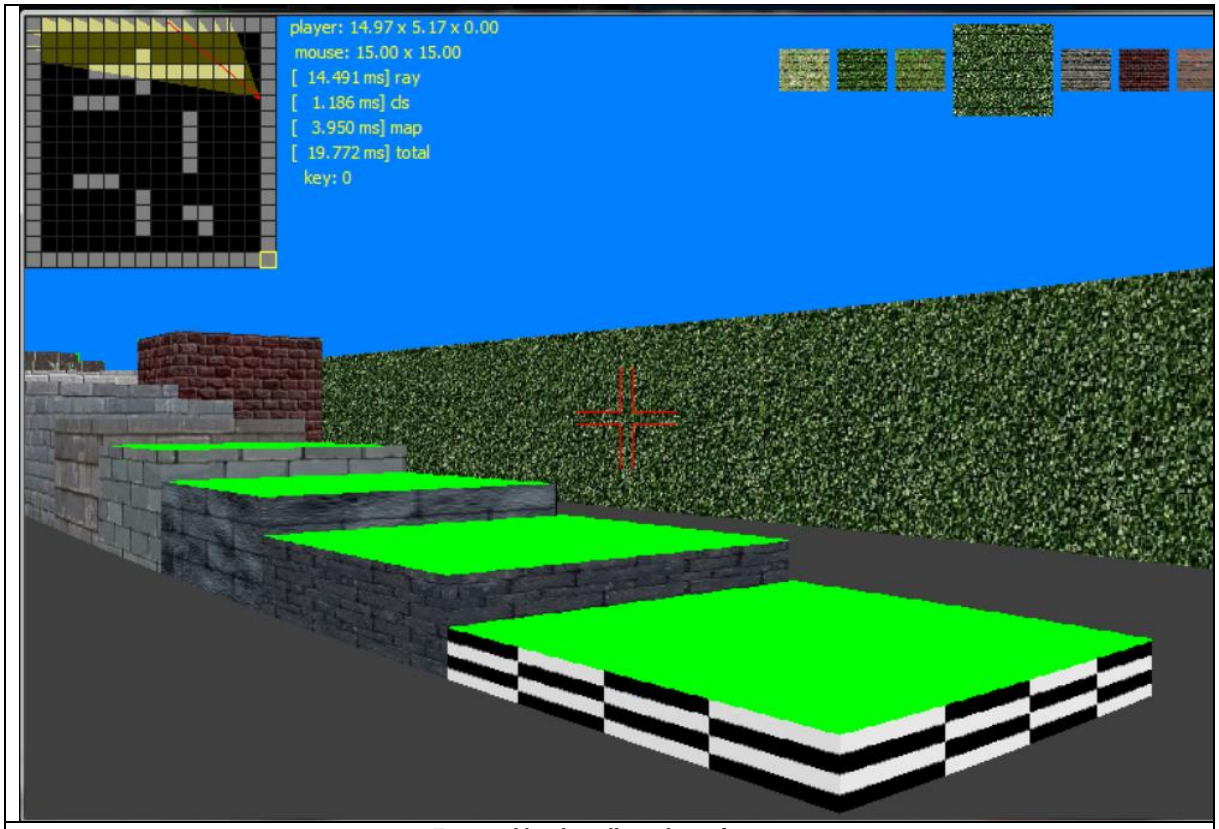




Example – window + reflective floor [the window is fake, it's not see-through]:

Part 20a – fractional wall heights

Inspired by the following examples:



Fractional height walls, with any fraction

I implemented this one in part 20a

Part 20b-c – performance improvements

How to probe OnUserUpdate() – start with the following break down, it probably will suffice, otherwise you can detail on this:

1. UserInput
2. Render loop x
    1. DDA part
    2. Collecting ray hit point data
    3. Render loop y
        1. Collecting data for rendering this pixel
        2. Actually rendering this pixel
3. Rendering minimap
4. Rendering debuginfo

Results (contents of **profiling part 20 for performance improvement 20230417.txt**):

```
Profiling data without any key activity (just starting position)
  * test ran for about 1 minute
  * in that time the PGE called OnUserUpdate() 1199 times
  * the "loop x" frequency corresponds with a screen width of 1200 pixels
  * the "loop x+y" frequency corresponds with a screen height of 720 pixels
  * > 95% of the time is in the pixel rendering part, maybe zoom in on that
  * FPS is about 19.66 on the average (= 1199 frames / 60.987 sec)



profiling stats for OnUserUpdate() and peripheral PGE time
-----------------------------------------------------------
Probe nr:  0 name: user input                          frequency:       1199 cum. musec:   818768 mean musec:   682.875732 (     1.681551 % )
Probe nr:  1 name: rndr loop x   - DDA part            frequency:    1438800 cum. musec:   915937 mean musec:     0.636598 (     1.881112 % )
Probe nr:  2 name: rndr loop x   - coll. hit point data frequency:    1438800 cum. musec:   563082 mean musec:     0.391355 (     1.156434 % )
Probe nr:  3 name: rndr loop x+y - coll. data f. cur pixel frequency:    1438800 cum. musec:    25275 mean musec:     0.017567 (     0.051909 % )
Probe nr:  4 name: rndr loop x+y - rendering cur pixel frequency: 1035936000 cum. musec: 46368180 mean musec:     0.044760 (    95.228996 % )
Probe nr:  5 name: rndr minimap                        frequency:       1199 cum. musec:        0 mean musec:     0.000000 (     0.000000 % )
Probe nr:  6 name: rndr debuginfo                      frequency:       1199 cum. musec:        0 mean musec:     0.000000 (     0.000000 % )
Probe nr:  7 name: engine time                         frequency:       1199 cum. musec:        0 mean musec:     0.000000 (     0.000000 % )

total means (musec):   683.966003
            (msec) :     0.683966
                   (   100.000000 % )
total mean fps     :  1462.060913

Process returned 0 (0x0)   execution time : 60.987 s
Press any key to continue.


After a couple of optimizations, I got the FPS pulled up to about 32.16 on the average. Afaic this suffices for the moment:

profiling stats for OnUserUpdate() and peripheral PGE time
-----------------------------------------------------------
Probe nr:  0 name: user input                          frequency:       2012 cum. musec:  1431982 mean musec:   711.720703 (     3.372966 % )
Probe nr:  1 name: rndr loop x   - DDA part            frequency:    2414400 cum. musec:  1553313 mean musec:     0.643354 (     3.658756 % )
Probe nr:  2 name: rndr loop x   - coll. hit point data frequency:    2414400 cum. musec:  1304507 mean musec:     0.540303 (     3.072705 % )
Probe nr:  3 name: rndr loop x+y - coll. data f. cur pixel frequency:    2414400 cum. musec:    46925 mean musec:     0.019435 (     0.110530 % )
Probe nr:  4 name: rndr loop x+y - rendering cur pixel frequency: 1738368000 cum. musec: 37318984 mean musec:     0.021468 (    87.903107 % )
Probe nr:  5 name: rndr minimap                        frequency:       2012 cum. musec:        0 mean musec:     0.000000 (     0.000000 % )
Probe nr:  6 name: rndr debuginfo                      frequency:       2012 cum. musec:   625944 mean musec:   311.105377 (     1.474382 % )
Probe nr:  7 name: engine time                         frequency:       2012 cum. musec:   173025 mean musec:    85.996521 (     0.407552 % )

total means (musec):  1110.047119
            (msec) :     1.110047
                   (   100.000000 % )
total mean fps     :   900.862671

Process returned 0 (0x0)   execution time : 62.553 s
Press any key to continue.
```

Part 21 – sprites / objects added

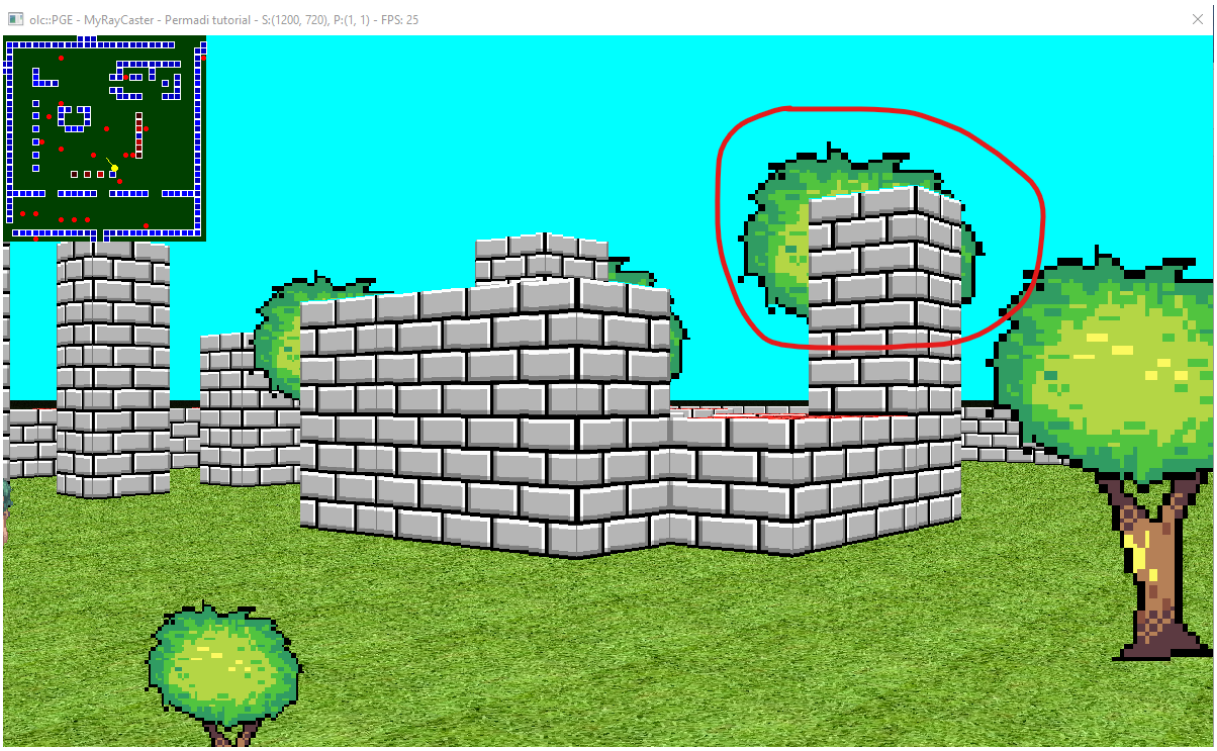
Adaptations to depth buffer (in comparison with the approach Javidx9 uses in his FPS vid part 2):

Line	Text
131	float *fDepthBuffer = nullptr; 1
235	fDepthBuffer = new float[ScreenWidth()]; 2
748	fDepthBuffer[x] = fCurDistance; 3
938	if (pSample != olc::BLANK && fDepthBuffer[nObjColumn] >= fObjDist) {
940	fDepthBuffer[nObjColumn] = fObjDist; 4

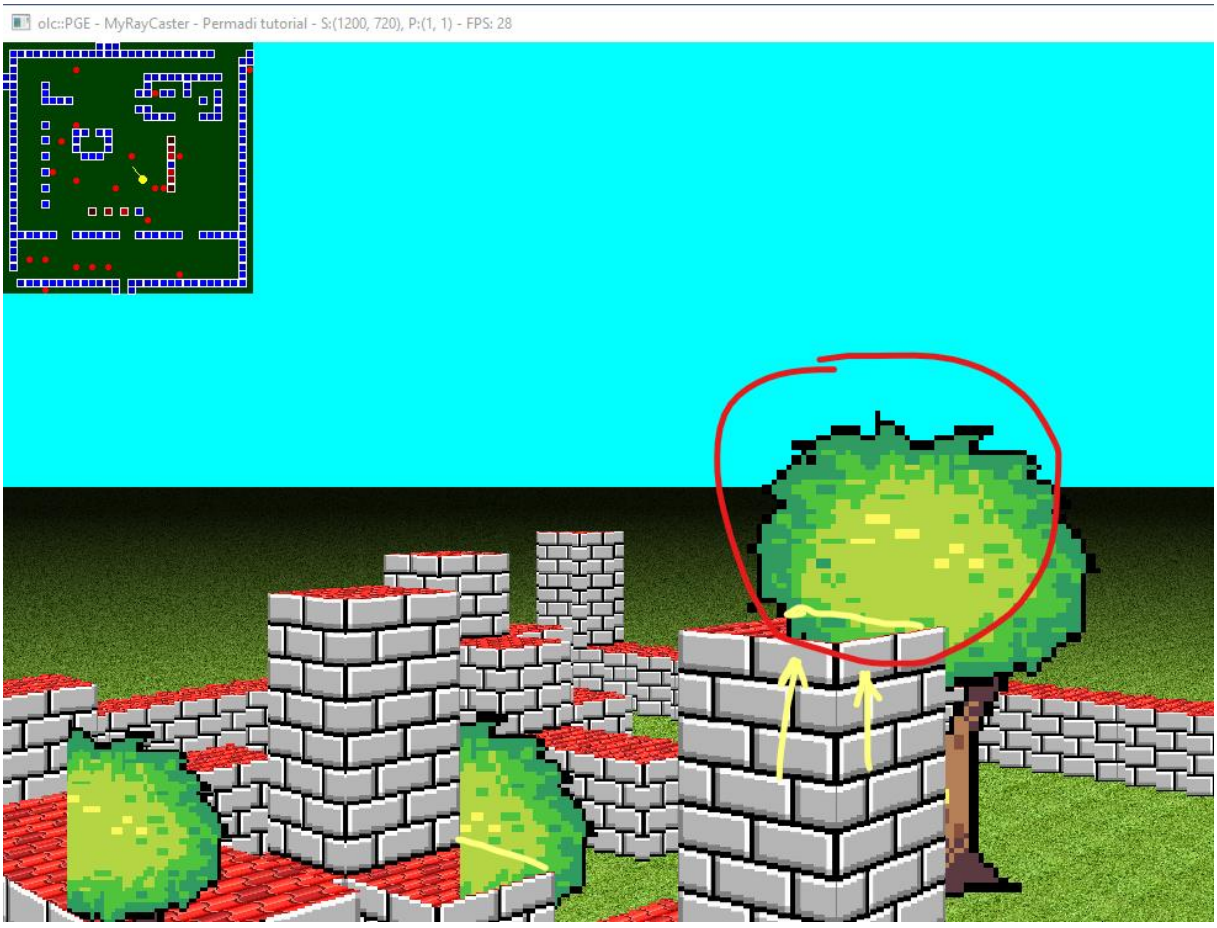
1. Declaration of pointer to depth buffer – no changes needed
2. Initialization – must be altered to make it 2D
3. Filling / updating of the depth buffer must be altered
4. Application of the depth buffer must be altered

After implementation it appears ok, but there are some strange artifacts.

Note this large tree behind the 3-level wall:



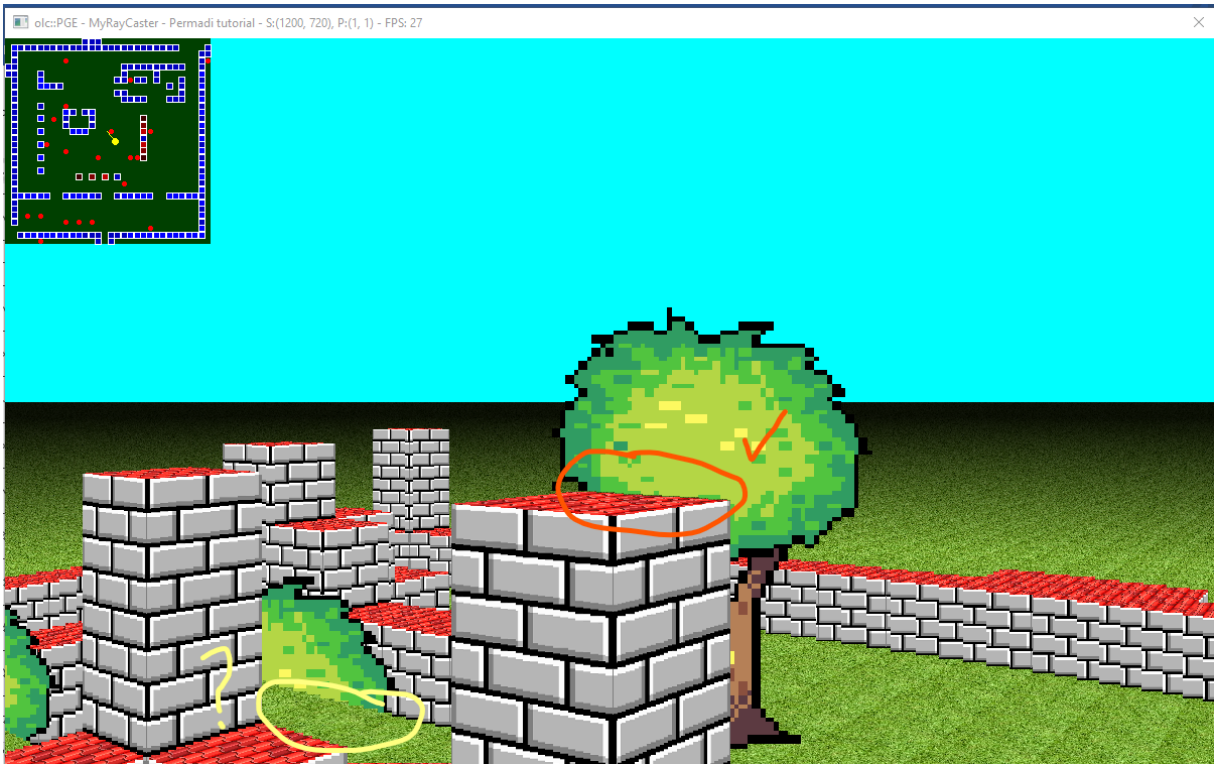
Look what happens if I elevate the player:



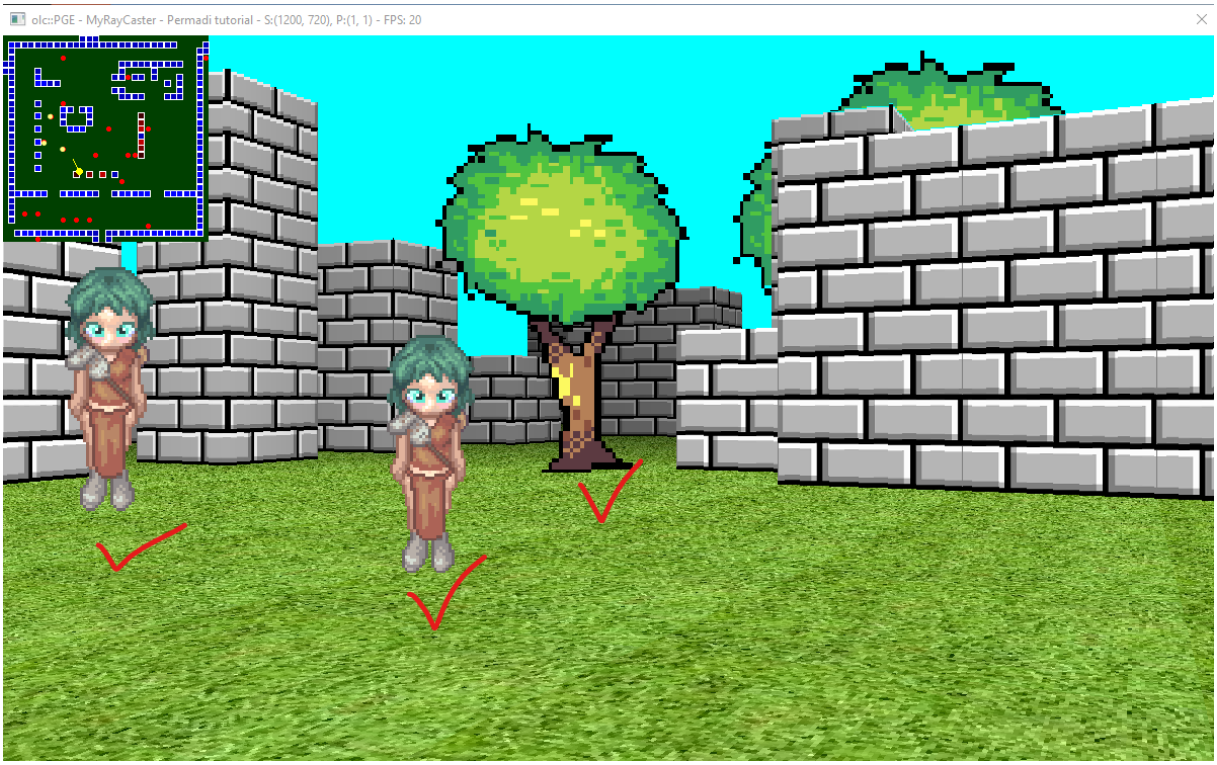
It doesn’t work properly in combination with roof rendering.

In the code I called these variables ceil_front and ceil_back, and I erroneously assumed they limited a surface that was seen from below…

So that was pretty easy to solve. But there are other artifacts still:

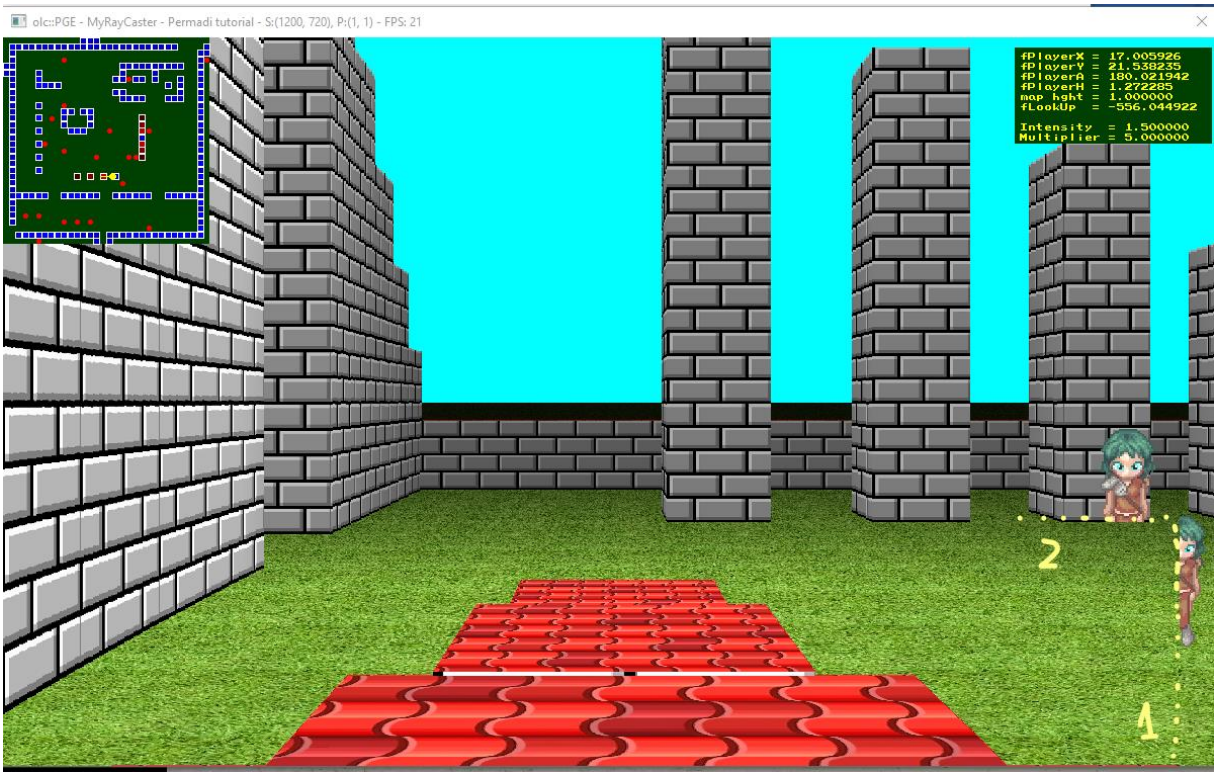


Why isn't the yellow part rendered properly?



These three objects (I tipped them yellow in the minimap) are rendered ok if I'm in front of the fractional wall…

… and get truncated when I'm above or behind the fractional wall



Check this scene:

- the player is right above the height = 1.0f block (see info HUD)';

- the forward of the two objects is only half rendered, along the boundary of said block (noted 1);
- the distant of the two objects is only half rendered, along the boundary of the wall rendering behind it (noted 2);

It looks like the depth buffer is filled there with the distance of the level 1 block, even though it isn't even visible.

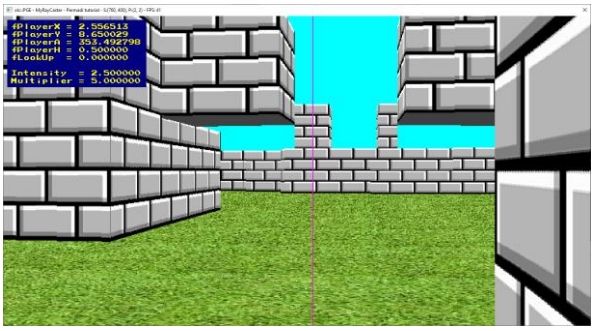
[Dunno how I fixed this, but I did 😊]

Part 22 – gaps, holes, bridges, overhangs (after refactoring of map representation)

To fix in multilevel ray caster experiment

1. **Get hit lists per level (instead of just the first hit)**

Consider this scene:

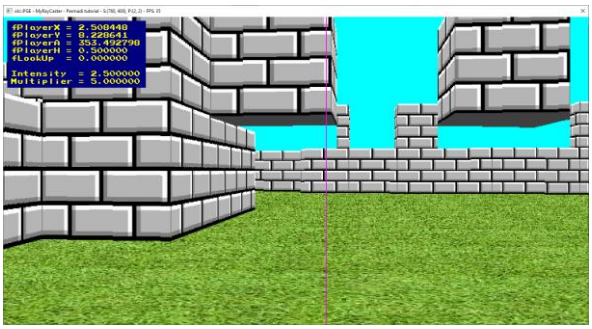


With hit list

```
hit pt: (14, 7.66329) map: (14, 7) dist: 11.4816, hght: 0, lvl: 0 bot - front: 228, back 226 top - front: 171, back 174
hit pt: (14, 7.66329) map: (14, 7) dist: 11.4816, hght: 0, lvl: 1 bot - front: 171, back 174 top - front: 114, back 122

from Y: 399 to Y: 229 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: FLOOR
from Y: 228 to Y: 200 hit point: (14, 7.66329) map location: (14, 7) distance: 11.4816, type: WALL
from Y: 199 to Y: 171 hit point: (14, 7.66329) map location: (14, 7) distance: 11.4816, type: WALL
from Y: 170 to Y: 114 hit point: (14, 7.66329) map location: (14, 7) distance: 11.4816, type: WALL
from Y: 113 to Y: 0 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: SKY
```

Clearly there's a far block behind the floating block, but it isn't rendered properly:



Hit list:

```
hit pt: (14, 7.54024) map: (14, 7) dist: 11.4955, hght: 0, lvl: 0 bot - front: 228, back 226 top - front: 171, back 174
hit pt: (7, 7.95957) map: (7, 7) dist: 4.49311, hght: 0, lvl: 1 bot - front: 127, back 140 top - front: -19, back 21

from Y: 399 to Y: 229 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: FLOOR
from Y: 228 to Y: 200 hit point: (14, 7.54024) map location: (14, 7) distance: 11.4955, type: WALL
from Y: 199 to Y: 171 hit point: (14, 7.54024) map location: (14, 7) distance: 11.4955, type: WALL
from Y: 170 to Y: 141 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: SKY
from Y: 140 to Y: 127 hit point: (7, 7.95957) map location: (7, 7) distance: 4.49311, type: CEIL
```

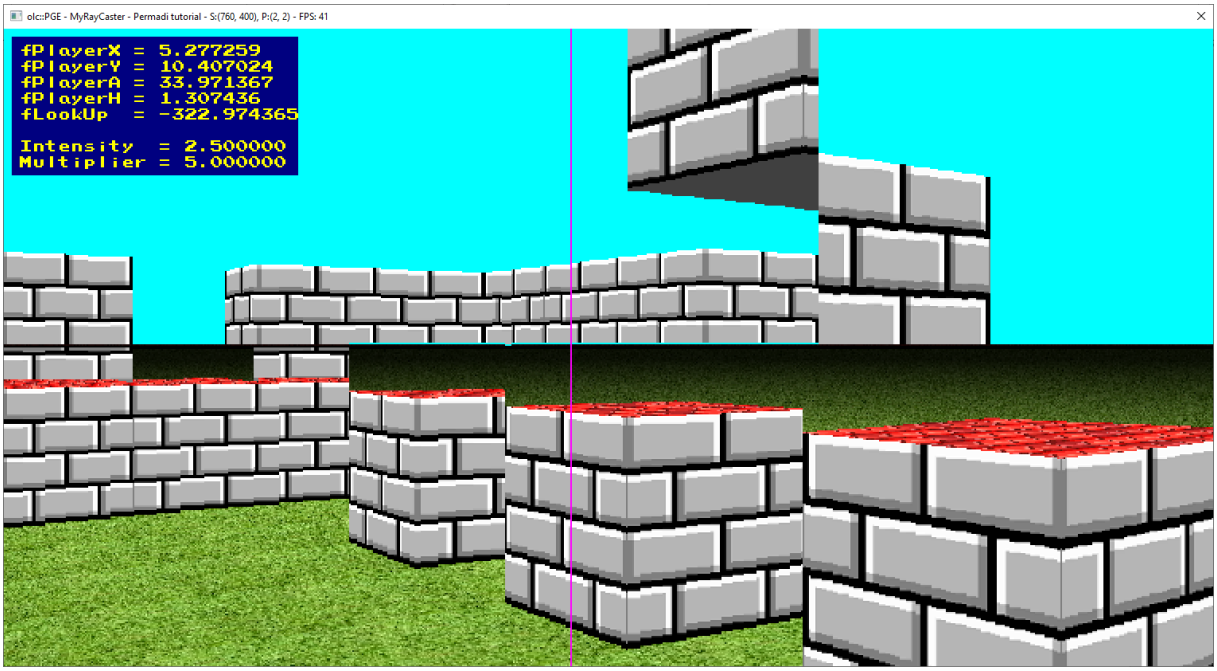
```
from Y: 126 to Y: 0 hit point: (7, 7.95957) map location: (7, 7) distance: 4.49311, type: WALL
```

This is caused by only taking one (actually two) hit point(s) per level. Since the ray on level 2 already found the floating block, it doesn't look further, and the far block behind it is not reported hence not rendered. I need to rebuild the DDA algo to get hit **lists** per level (again) iso just the first hit.

Note that the hitlists are consistent however 😊

2. Next problem

Consider this scene and hitlist:




```
hit pt: (9.41456, 13) map: (9, 13) dist: 4.88004, hght: 0, lvl: 0 bot - front: 375, back 354 top - front: 241, back 236
hit pt: (12.6057, 15) map: (12, 15) dist: 8.64408, hght: 0, lvl: 1 bot - front: 223, back 222 top - front: 147, back 150

from Y: 399 to Y: 376 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: FLOOR
from Y: 375 to Y: 241 hit point: (9.41456, 13) map location: (9, 13) distance: 4.88004, type: WALL
from Y: 240 to Y: 236 hit point: (9.41456, 13) map location: (9, 13) distance: 4.88004, type: ROOF
from Y: 235 to Y: 200 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: FLOOR
from Y: 199 to Y: 241 hit point: (9.41456, 13) map location: (9, 13) distance: 4.88004, type: WALL
from Y: 240 to Y: 236 hit point: (9.41456, 13) map location: (9, 13) distance: 4.88004, type: ROOF
from Y: 235 to Y: 224 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: SKY
from Y: 223 to Y: 147 hit point: (12.6057, 15) map location: (12, 15) distance: 8.64408, type: WALL
from Y: 146 to Y: 0 hit point: (-1, -1) map location: (-1, -1) distance: 22.6274, type: SKY
```

Something's really going wrong with the assembly of the render list here. The green part is built OK, but

- the first yellow line (type FLOOR) shouldn't be there,
- the cyan line has it's A and B values switched for some reason, and
- the second yellow line is a duplicate (of three lines up)

What's going wrong here? And why does it happen here, but not elsewhere?

Summary – I got some fixes, but in the end I ran down due to complexity and adding more bugs than I fixed. Stored this not working result as main - part 21 (holes and bridges) - FAILED ATTEMPT.cpp.

I have to give this a retry in steps:

1. First refactor the code to work with the new map modelling method, where each level is defined separately to make holes and bridges possible. But don't put them in yet!

2. You can build up the height per level by combining both the level and the height value in that level. This way it should be possible to create fractional walls on upper levels.
3. Now introduce the ray casting per level technique like before, differentiating hits only when the level alters along the ray track. This prevents very long ray casting traces.
4. An alternative would be what I did for Games raycaster – just store the info at every intersection, and let the rendering sort out the ray trace. The DDA will be simpler, the rendering possibly a bit more complex.
5. If all this works well, introduce holes, bridges and floating blocks (in that order) and test thoroughly.

Notes on new method of multilevel raycasting

Joseph21
May 15, 2023

Part 22a – introducing RC_Map

Header comment:

```
In preparation of the alternative rendering method I added a class RC_Map that has the new map representation. Instead of one 2D
datastructure that represents heights, I have the maps modelled now in a layered fashion, so that I can approach the layers
separately for the raycasting.

Besides adding the new class RC_Map, I implemented it in little code changes where necessary.
```

This new object class RC_Map is a straightforward refactoring of the way the map was handled before. Nothing special is done or added, the only thing that is done is that the game map functionality is properly contained in the RC_Map object:

- Some of the PGE derived class variables are moved to the RC_Map class, like map dimensions, string variable that defines the map, and the float * that is used to initialize the height values of the map.
- The initialization of the map is done now using a call to RC_Map::InitMap() method.
- Furthermore, the RC_Map has methods for
    - Determining the max distance (i.e. the length of the map diagonal)
    - Determining whether a tile coordinate is in bounds of the map
    - Returning the height of the map at any map coordinate pair

Part 22b – adapted the way the map is represented in the program

Header comment:

```
Having added a new class RC_Map this version of the program is the first rebuild of the map representation in layers. The map is
predefined as a number of 2d string variables, and added as layers one by one.

Note: there are no holes or overhangs or floating blocks yet, just rendering the same map using a different internal representation.
```

In this step I created the same rendering of the same world scene with a different “under the hood” map representation in the code. This step lays the necessary groundwork of what I want to achieve.

- Instead of one (std::string represented) 2d map of characters where each character indicates the height at that tile, the new method uses a 2d map of character *for each layer of the map*. So the map consists of one or more layers, is defined per layer, and is inited by stacking these layers on top of each other. This makes it possible for a tile at for instance layer 1 to be filled,

while the same tile at layer 0 is empty. This is what we need to make gaps, bridges and overhangs.

- So the initialization of the map is done per layer. Having fractional height cells makes it possible that a cell is not height 1, it could be less (but it shouldn't be larger than 1, because that's in the realm of the next layer). For this implementation each cell bottom rests on the "ground floor" of the layer where it lives. So all cells that live at layer 2 have their bottom at world height 2.0f.
- I made sure to keep the interface of RC_Map largely compatible with what it was before, and made the changes mostly inside the RC_Map class.
- Instead of calling RC_Map::InitMap() with one large string from OnUserUpdate(), I now define several layers (as separate strings) before and add them one by one to the map object.

Didn't alter the ray casting and rendering itself. This step is focused on getting the RC_Map object working for the new representation.

Part 22c – working version, albeit with bugs in the texturing of roof and ceiling

Header comment:

```
* In the previous approach, slices were built up on a per pixel basis: starting from screen bottom for each pixel a check was made if
  that pixel fell within a range. In the new approach, slices are built per hit point (i.e. per potentially visible block) - first
  the floor and sky are drawn, then the hit points are rendered on top using a combination of painters algo and depth buffer drawing.
* To get the new approach working properly I made the following adaptations:
    + added test code to output hit point list at a specific slice (F1-F2 to move test slice left or right, T to output it)
    + extended struct sIntersectInfo with new members to support ceiling rendering and new approach
    + Altered the DDA function to work within a specified level of the map
    + Created an alternative function for the projections of block tops and bottoms on the screen (CalculateWallBottomAndTop2())
    + Changed the lambda to sample ceilings - to match the root sampling lambda
    + Removed the STRETCHED_TEXTURING, since the new approach is per block and all rendering is not stretched anymore.

* I also did some small maintenance things:
    + removed now obsolete colour constants
    + block terminology was "ceil" now "top"
```

- Before I couldn't look at a cell from below (i.e. see its ceiling). Now I can, so I added fDstBack (distance to back face of the cell) where I already had fDstFrnt (distance to front face of the cell)[8]
- I already had bottom_front, ceil_front and ceil_back to denote the (on screen) projected heights of the cell boundaries. I completed this set of variables by adding bottom_back, and renamed at the same time to bot_front, bot_back, top_front, top_back[9];
- I had to adapt the DDA algorithm so that I could cast rays at each layer (or level) of the map. It's not guaranteed anymore that a solid cell on layer n will be supported by a solid cell on layer n-1, so I need to cast rays at each layer of the map.
- This also implied that each hit point must be associated with the layer of the cell that was hit. So I added this to the IntersectInfo structure as well.
- The new approach also implies that projections are calculated per cell (and not per column of cells as before), so I adapted CalculateWallBottomAndTop() into CalculateWallBottomAndTop2() to do just that.
- Like before after the ray casting (DDA part) the list of hit point is elaborated by calculating for each hit point the *on-screen projection height* for that cell (the four values for bot_front, bot_back, top_front, top_back). After that, the rendering takes quite a different approach:

[8] The front face is the face where the ray enters the cell, the back face is the face where the ray leaves the cell.
[9] The terminology ceiling as the upper face of the cell became confusing, since I now considered the ceiling to be the face at the bottom of the cell.

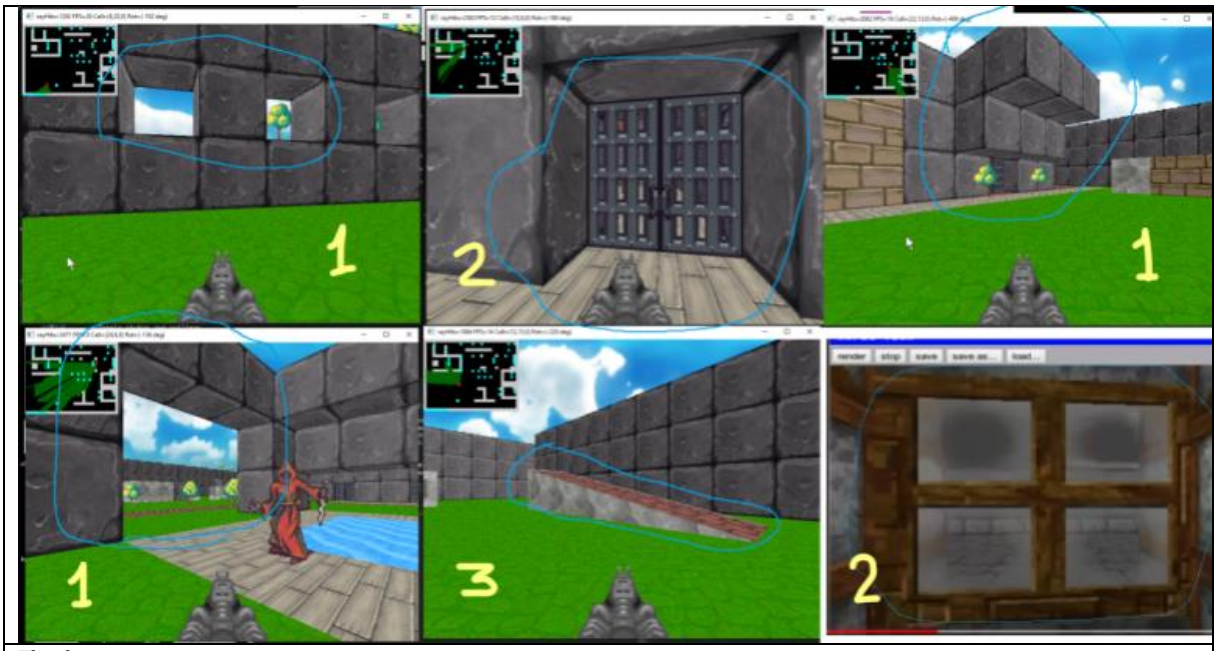
- Prepare the screen slice by drawing floor and sky in it, using the horizon height as delimiter.
- Then render all of the hit point records, drawing the wall segments, and ceiling or roof where appropriate (this is determined using the values for bot_back/bot_front resp. top_back/top_front).
- All subsequent draw calls are done using the depth buffer. So segments that are further away get overwritten with segments that are close by.
- For now I also sort the hitpoints – so the approach is a combination of painters algorithm and depth buffer. There are glitches still in the rendering of roof / ceiling vs wall, and sorting helps keeping these glitches manageable.

Part 22d – bugs in texturing of roof and ceiling fixed, collision detection updated

Header comment:

```
* After the rebuild of the rendering mechanism in the previous version, this code only contains bug fixes for rendering the roofs and
  ceilings. Check the Permadi tutorial and make your own sketch with pen and paper to comprehend the fixes.
* Fixed collision detection on the map as well, since this contained bugs due to the rebuild to the alternative map representation
```

Re-evaluating ambitions



The above images were given to me as inspiration:
Marked 1 – gaps, bridges and overhanging walls;
Marked 2 – Doors, fences or windows with partial see through
Marked 3 - Ramps

Sub Marked 1 – I did an attempt, but couldn't manage it first time. After multiple attempts I got this working ok now 😊 (part 22)

Sub Marked 2 – This may be feasible by rendering these doors, fences or windows as objects (i.e. *after* the background scene) and apply some alpha blending where necessary

After just one attempt I got something working, which needed a bit of fixing of the DDA algorithm – if you hit a transparent block you must record it as a hit point, but not let it influence the DDA.

Implemented this in part 23e

Idea 1

I think depth buffer doesn't always give the right effect, since the hight differences are not taken into account. This can cause problems because in the depth buffer walls can have smaller distances than the roof that is on top of that wall (and looked upon).

The fix can be to calculate the angle looking down or up using the screen pixel you are looking through, the horizon height and the field of view:

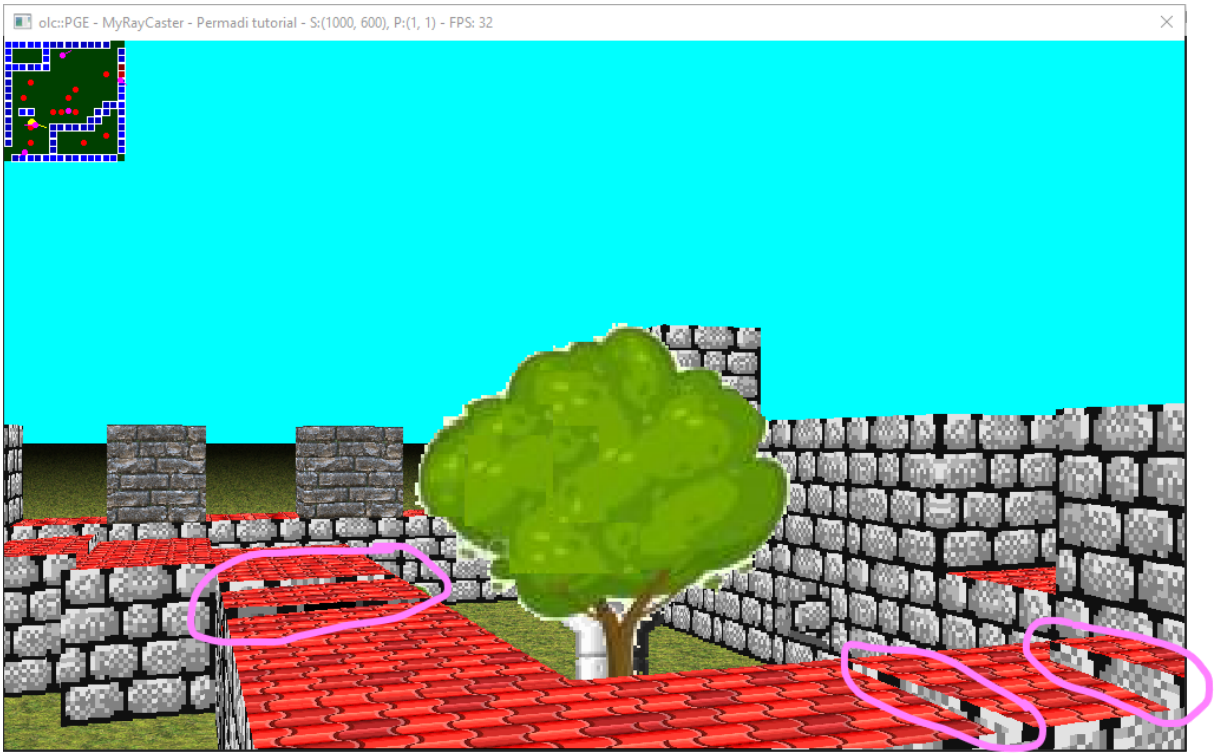
Let fAnglePerPixelRatio = fFoV / ScreenWidth()

Apply this on the screen y coordinate to get the angle looking up or down. Note that this assumes that pixels are evenly spaced horizontally AND vertically, but that's a safe assumption.

Multiply the cosine of this angle to the distance you pass in DrawDepth(), not only for floors, but also for walls and objects. This should compensate for additional distance due to height differences, and thus yield a better approximation of the actual distance / depth of the pixel drawn (consequently removing the erroneous effects).

Implemented this, but still have glitches in rendering of ceilings and roofs in some places. It only occurs in certain conditions, but didn't find how to fix this properly yet.

Look at this scene:



The rendering of roofs is buggy where there's a transparent block. It is OK where there's a regular block.

Under the big "bridge" it's failing where there are fractional blocks… What is going wrong??

Idea 2

I could get rid of the atan2f() call for wall rendering, by letting the DDA function calculate and return the face direction that was hit. This should be relatively easy, since you have the x-step and y step (both are either positive or negative) and you know if the hit point is on a horizontal or vertical grid line.

Look at below table. When hitting a vertical grid line, you can determine EAST or WEST by looking at the x-step value. When hitting a horizontal grid line, you can determine NORTH or SOUTH by looking at the y-step value:

		hit point is on … grid line	
		horizontal	***vertical***
x-step	***< 0***		EAST
	> 0		WEST
	== 0		-
y-step	***< 0***	SOUTH	
	> 0	NORTH	
	== 0	-	

In the DDA algorithm all this info is available, and it comprises max. two easy comparisons per hitpoint. I expect the saving of the atan2f() call to be beneficial for performance.

Upon introducing block associated objects, this only gains in relevance…

Implemented this, and it works fine. It doesn't provide much performance gain though.

Notes on the evolution of CalculateWallBottomAndTop()

May 8, 2023

1 Basic calculation of wall projection on screen (ref. part 09b)

At the very beginning of the series, the players height is set to be halfway the height of a block/wall. Since I use walls with unit height (i.e. height of 1.0f), the players height is 0.5f.

See for instance this part of the code (from Part 09b) to calculate the wall top and bottom projections on the screen (these are called ceiling and floor in this snippet) for a specific slice:

```
// make correction for the fish eye effect
fCorrectDistToWall = fRawDistToWall * cos( fViewAngle * PI / 180.0f );
int nSliceHeight = int((1.0f / fCorrectDistToWall) * fDistToProjPlane);
nWallCeil  = (ScreenHeight() / 2.0f) - (nSliceHeight / 2.0f);
nWallFloor = (ScreenHeight() / 2.0f) + (nSliceHeight / 2.0f);
```

The wall part of this slice is symmetrical around the horizon (represented here as `ScreenHeight() / 2.0f`*): half of the wall is above the horizon and half of the wall is below the horizon.*

2 Adaptation for variable height walls (ref part 14a)

With the introduction of variable height walls, I put the projection calculation code[10] into its own function - the first version of function `CalculateWallBottomAndTop()`:

```
// This function calculates the y screen coordinates of the bottom and ceiling of a wall slice that has
// a certain height and is at a certain distance from the player / viewpoint
void CalculateWallBottomAndTop( float fCorrectedDistToWall, int nWallHeight, int &nWallTop, int &nWallBottom ) {
    // calculate slice height for a *unit height* wall
    int nSliceHeight = int((1.0f / fCorrectedDistToWall) * fDistToProjPlane);
    // offset wall slice height from halfway screen height (horizon) - take wall height into account
    nWallTop    = (ScreenHeight() / 2) - (nSliceHeight / 2.0f) - (nWallHeight - 1) * nSliceHeight;
    nWallBottom = (ScreenHeight() / 2) + (nSliceHeight / 2.0f);
}
```

In this adapted version, first the projected height of one slice is calculated, like before. For the basic ray caster this sufficed since all walls were exactly 1 high. With the introduction of variable height walls they can also be 2, 3 high, or even higher. So I had to make an adaption to the calculation of nWallTop, where any additional height must be accounted for.

Example: consider a wall of height 2, still 0.5 of that wall slice is below the horizon, but now 1.5f of that wall slice is above the horizon. Suppose nWallHeight == 3, then nWallTop becomes 2.5f times the height of one slice above the horizon.

3 Adaptation for looking up and down (ref part 16)

When you implement looking up or down, you basically just shift the rendering of the scene down or up along the screen. This means that the horizon shifts along the screen as well, and the expression `ScreenHeight() / 2.0f` no longer suffices as the horizon height. Therefore in this slightly adapted version the height of the horizon (in screen space / pixel space) is passed as an argument:

```
// This function calculates the y screen coordinates of the bottom and ceiling of a wall slice that has
// a certain height and is at a certain distance from the player / viewpoint
void CalculateWallBottomAndTop( float fCorrectedDistToWall, int nHorHeight, int nWallHeight, int &nWallTop, int &nWallBottom ) {
    // calculate slice height for a *unit height* wall
    int nSliceHeight = int((1.0f / fCorrectedDistToWall) * fDistToProjPlane);
    // offset wall slice height from halfway screen height (horizon) - take wall height into account
    nWallTop    = nHorHeight - (nSliceHeight / 2.0f) - (nWallHeight - 1) * nSliceHeight;
    nWallBottom = nHorHeight + (nSliceHeight / 2.0f);
}
```

All calculations are exactly the same as before, the only difference is that `ScreenHeight() / 2.0f` *is replaced by a parameter* `nHorHeight`*.*

[10] I also renamed the variables, but that's beside the point here

4 Adaptation for crouching and flying (ref part 17a)

This version took me a while to figure out, because as a consequence of flying / crouching the players' height becomes variable. After a while I realized that for previous versions of this code the slice stuck out halfway below and above the horizon **as a consequence of the player having height 0.5f**. After that little discovery, the coding became easy:

```
// Returns the projected bottom and top of a wall slice as y screen coordinates.
// The wall is at fCorrectedDistToWall from eye point, nHorHight is the height of the horizon
// and nWallHeight as the height of the wall (in blocks) according to the map
void CalculateWallBottomAndTop( float fCorrectedDistToWall, int nHorHeight, int nWallHeight, int &nWallTop, int &nWallBottom ) {
    // calculate slice height for a *unit height* wall
    int nSliceHeight = int((1.0f / fCorrectedDistToWall) * fDistToProjPlane);
    nWallTop    = nHorHeight - (nSliceHeight * (1.0f - fPlayerH)) - (nWallHeight - 1) * nSliceHeight;
    nWallBottom = nHorHeight + (nSliceHeight *          fPlayerH );
}
```

Again, the calculation has only changed a bit. Before the offset from the origin height was `(nSliceHeight / 2.0f)`*, which is the same as* `(nSliceHeight * 0.5f)` *which is the same as* `(nSliceHeight * (1.0f - fPlayerH))` *and* `(nSliceHeight * fPlayerH)` *(assuming that* `fPlayerH` *remains fixed at 0.5f)*

Suppose you leave out the multilevel wall part (nWallHeight == 1 so that nWallHeight – 1) == 0) and have the player height clamped between 0.0f and 1.0f, you should see that:

- *If* `fPlayerH` *== 0.0f → the complete slice height is above the horizon, i.e. the bottom of the slice is exactly on the horizon and the top sticks out one slice height above it. This corresponds with the players view point being on the ground.*
- *If* `fPlayerH` *== 1.0f → the complete slice height is below the horizon, i.e. the top of the slice is exactly on the horizon, and the bottom is 1 slice height lower on the screen than the top. This corresponds with the players view point being at the height that the wall is.*

5 Adaptation for alternative map representation (ref part 22d)

Up until part 22c, the map used to be defined as a 2D string, where each character in that string denoted the height of the wall at that tile of the map. All walls were always complete columns of 1 or more blocks, from the ground up. Therefore this representation wasn't useable for implementing gaps, bridges and floating blocks, so I rewrote the map representation: in the new representation the map is created as a series of layers, so *each block is defined within its own level* of the map, and has a maximum height of 1.0f within that level.

This meant I had to reason about "wall height" in a different way. It used to be: "the size from ground level to the height I chose it to be", but that wouldn't allow for holes, gaps, bridges. *From now on I look at individual blocks that exist on a specific level of the map.*

Because I also introduced fractional block height, the block height within a level is a `float`, whereas the level itself is an `int`. Here's the adapted (and for now final) version of the function:

```
// Returns the projected bottom and top (i.e. the y screen coordinates for them) of a wall block.
// The wall is at fCorrectedDistToWall from eye point, nHorHight is the height of the horizon, nLevelHeight
// is the level for this block and fWallHeight is the height of the wall (in blocks) according to the map
void CalculateWallBottomAndTop2( float fCorrectedDistToWall, int nHorHeight, int nLevelHeight, float fWallHeight,
                                 int &nWallTop, int &nWallBottom ) {
    // calculate slice height for a *unit height* wall
    int nSliceHeight = int((1.0f / fCorrectedDistToWall) * fDistToProjPlane);
    nWallTop    = nHorHeight - (nSliceHeight * (1.0f - fPlayerH)) - (nLevelHeight + fWallHeight - 1.0f) * nSliceHeight;
    nWallBottom = nWallTop + nSliceHeight * fWallHeight;
}
```

Changes in this function w.r.t. the previous version:

- *Another parameter is added:* `nLevelHeight`*, denoting the level where this block lives.*
- *The* `fWallHeight` *parameter is still there, but its interpretation differs*[11] *– it now only denotes the height of the block within the level. So it can be any number in the range (0.0f, 1.0f]*[12]
- *The calculation of the slice height of a unit height wall is still the same.*
- *The calculation of* `nWallTop` *is still the same, however the height of the block is now represented by* `nLevelHeight + fWallheight`
- *The bottom is now just the correct fraction of a unit slice height below the top of this block*

So this version of the function doesn't project the wall (as a complete column of blocks stretching out over multiple levels), but it projects only one block at one level. Again, to introduce gaps, bridges and floating blocks it's necessary to look at the map as individual blocks that live on a level.

For the future I want to extend the concepts so that fractional blocks can also start at some fraction from the level base.

Notes on refactoring my part 23 g ray caster code

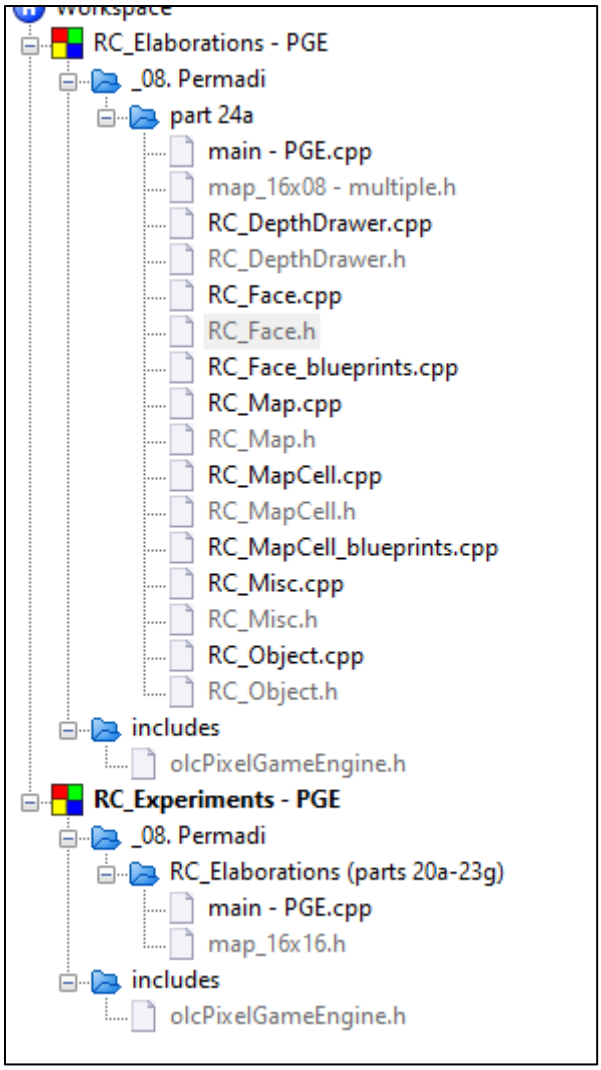
June 11, 2023

Intro

I made a lot of progress since part 23g of my "permadi elaborations". So much in fact that I face the task of breaking all these additional functionality into the nice step by step required to publicate them.

So the central question here is: ***How to step-by-step my achievements for part 24a?***

[11] Maybe I should've changed the name of the parameter to emphasize this…
[12] Technically it could be 0.0f as well, but there's little point in defining blocks with no height.



(See the project structures for part 23 g and part 24 a in the figure)

Goal(s)

The goals are to split all the changes made between part 23g and current version of part 24a (at 09-06-2023) in two separate phases:

1. Refactor phase - First a refactor in the module structure that I currently use, while keeping the code as much "as is" as possible;
2. Then step by step – add all the functionality that was added the last weeks/month (and make a list of future work in the process)

Refactor phase – approach and progress

- Cyan – no action required
- Yellow – not done yet (i.e. postponed till phase 2)
- Green - done

Step	Consideration	Implementation note(s)
1. Use RC_Elaborations part 23G as the basis to start from, and rebuild your achievements step by step from that code:	• The basis only consists of two files, the main – PGE.cpp, the	File path to sprite files had change.

Step	Consideration	Implementation note(s)
	olcPixelGameEngine.h include file and a map 16x16 – part 23g.h file	Some sprite file names had changed.
2. First isolate RC_Misc functions (put in separate module);	• Rename "Block" to "MapCell" from the start; • Demo code for GameBrothers – remove! • Some code is added to implement dynamic map cells • Improvements were made w.r.t. delayed rendering for ceilings and roofs • Sense radius was added in rendering minimap	Since the demo code for GameBrothers was added later, I didn't have to remove it.
3. Isolate RC_Face functions (this should lead to something similar to backup 20230512);	• See above notes	
4. Isolate RC_MapCell functions;	•	Done – Portal map cells were ignored for now Map cell blueprint are still part of RC_MapCell.cpp
5. Isolate RC_Map functions (this should lead to something similar to backup 20230523a);	•	Done
6. Isolate the face blueprints and the map cell blueprints (this should lead to something similar to backup 20230602);	•	Done
7. Isolate RC_DepthDrawer functions (should be combined with next);	•	Done
8. Isolate RC_Object functions (could be combined with previous - this should lead to something similar to backup 20230607);	•	Done

Notes on differences

After having refactored my code to be in the same file / project structure, I made a list of all the differences/improvements per module. I used the following source code maps to determine the differences from:

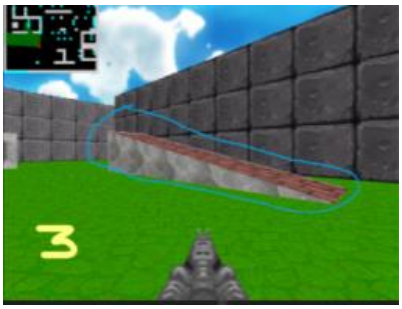
- working backup 20230609
- part 24i - refactoring finalized

Using that list of differences I decided on the priority and ordering of implementing each difference, and created a phasing of the refactoring process. I implemented the refactoring along these phases:

File	Versions: **part 24i - refactoring finalized** and **working backup 20230609** Difference	Prio/ordering	note
Map_16x16h vs Map_16x08 – multiple.h			
	Header comments	1	
	#include RC_Face.h	1	
	#include RC_MapCell.h	1	
	Different files for walls, roofs and floors	9	Solve later
	More object files – bushes and trees	9	Solve later
	vSkyColours added	5	after multiple map implementation
	Different map buildup: (old): one layer is just a string, (new): one layer is a vector of strings	4	multiple map implementation
	Multiple maps instead of just one	4	multiple map implementation
	vMapPortals added	6	portal implementation
	Maps have different dimensions (both x and y and z)	5	after multiple map implementation
RC_DepthDrawer			
	Overloaded Reset() added to clear just a piece of the depth buffer	9	Solve later
RC_Face			
	Comments are corrected and completed	1	
	Parameter list of AddFaceBluePrint() is limited to one FaceBluePrint type ref	1	blueprint input data improvements
	Declaration of methods is improved / corrected	1	
	Variable member names are improved	1	
RC_Face_blueprints			
	vFaceBluePrintLib is removed	1	where to? (ig RC_Face)
	Functions AddFaceBluePrint() and InitFaceBluePrint() are removed…	1	where to? (ig RC_Face)
	Definition of the blueprints is slightly changed	99	ignore
RC_Map			
	Member variables of RC_Map have been revised: z dimension is added, floorsprite pointer and skycolour	4	multiple map implementation
	Member variables of RC_Map have been revised: portal list is added	6	
	The size of the maps have become flexible, other parameters to InitMap()	5	after multiple map implementation
	The size of the maps have become flexible, other parameters to InitMap()	6	
	Slightly changed getters	4	multiple map implementation
	Added DiagonalLength3D()	4	multiple map implementation
	Added overloaded IsInBounds() (with 3 dimensions)	4	multiple map implementation
	Added getters and setters for floor sprite pointer and sky colour	5	after multiple map implementation
	Added private method GetPortalDescriptor()	6	portal implementation
RC_MapCell.h			
	Added definition of type PortalDescriptor	6	portal implementation
	Struct MapCellBluePrint is redefined wrt Boolean flags	1	portal denoting boolean skipped at prio 1 must be done at portal implementation
	Function AddMapCellBluePrint() now only takes one parameter of type MapCellBluePrint ref.	1	
	Improved comments	1	
	GetMapCell-BPID(), -BPHeight() and -BPFaceIx() have been removed since not used	1	
	Added derived class RC_MapCellPortal	6	portal implementation
	Added derived class RC_MapCellDynamic	3	dynamic implementation
	Functions AddMapCellBluePrint(), InitMapCellBluePrints() and GetMapCellBluePrint() are added	1	
RC_MapCell_blueprint			
	The definitions of the map cell blue prints is slightly altered, more bool members were added	1	
	Functions AddMapCellBluePrint(), InitMapCellBluePrints() and GetMapCellBluePrint() are removed	1	moved to RC_MapCell
RC_Misc			
	More standard include files were added	1	
	The mod functions got an additional parameter to offset the mod left range from zero	1	
	A generic mod() was defined, and mod360() resp. mod2pi() are defined in terms of this generic mod()	1	
RC_Object			
	Improvement of member variable names	1	
	Additional bAnimated flag	1	
Main			
	Quite different header comments	9	Solve later

File	Versions: **part 24i - refactoring finalized** and **working backup 20230609** Difference	Prio/ordering	note
	SENSE_RADIUS and other constant for minimap rendering added	2	small improvements
	Other map definition file	99	ignore
	Multiple map (and map counter) iso just one	4	multiple map implementation
	HUD debuginfo is split into PlayerInfo and ProcessInfo	2	small improvements
	Improvement on RayType, containing explicit start point now	2	small improvements
	Recursion statistics variables	7	recursive slice renderer
	Info on the sprites loaded is put to cout	2	small improvements
	Map creation and init is different due to multiple maps	4	multiple map implementation
	Random object generation is different due to more object sprites (bushes and trees)	9	Solve later
	Naming of member variables for intersectinfo is improved. Some members are added	5	after multiple map implementation
	DDA function is renamed and more explicitly parameterized	2	small improvements
	Function RenderSubslice() is added, which contains lot of the code that previously was in OnUserUpdate() to render background scene	7	recursive slice renderer
	In the game logic part code is added for the portal map cells	6	portal implementation
	Method RenderMap() is altered to be able to render only one level, or render all levels	2	small improvements
	The “sense radius” is drawn around the player to show that he is within door opening range	2	small improvements
	Other improvements to RenderMapRays()	2	small improvements
	Implementations of HUD rendering functions for Player and Process info	2	small improvements

Ambitions / future work



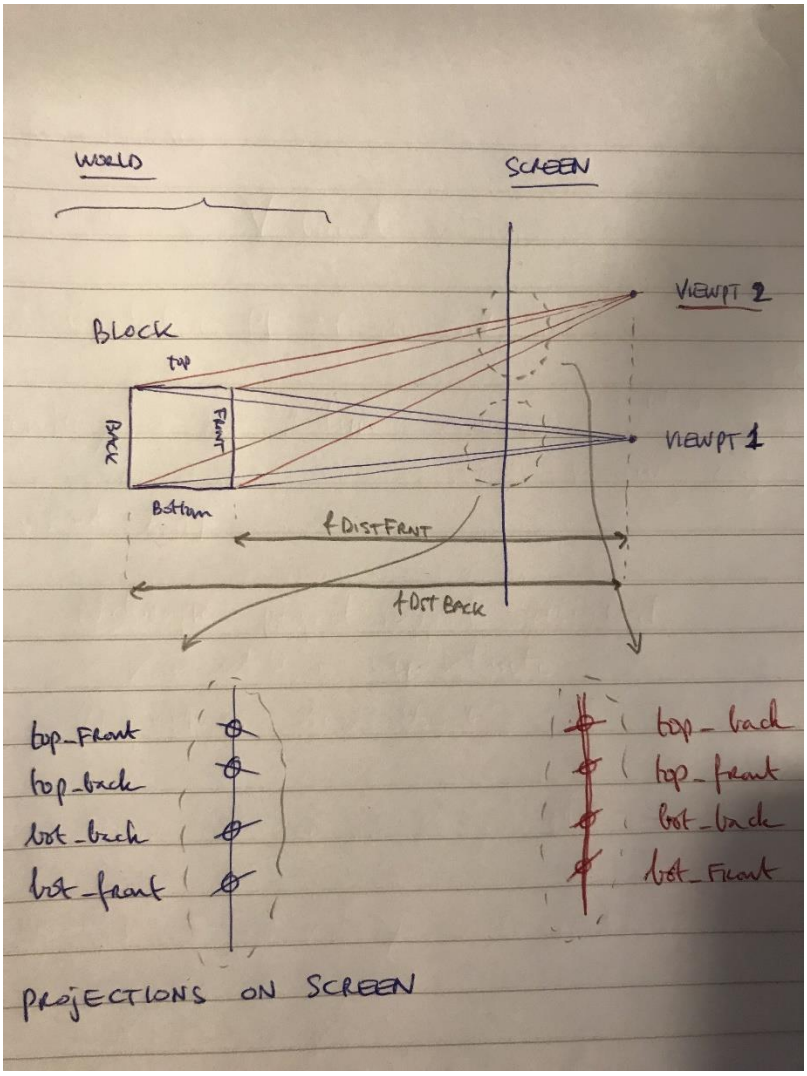
More ideas:

1. Sub part 3 – this is future work, I have no idea atm how to implement this in ray casting
2. Idea 4 – fractional blocks that don't start at relative level height 0.0f
3. Idea 5 – blocks moving up & down
4. Idea 6 - Animated wall objects, like opening doors - Implemented April 28, 2023
5. Idea 7 – improvement on player physics
6. Have static non transparent wall face objects be animated as well (so that you can animate lava)
7. Have columns of blocks grow and shrink gradually i.e. have their height be dynamically changing (by f.i. 0.1f * fElapsedTime to raise or shrink 1 block per every 10 seconds) → have been working on this in recent version (after 23g)
8. For the scaling –
    a. go back to the initial object / sprite rendering conform Javids part 2 fps vid.
    b. Set scaling on the difference between bottom and ceiling after calculating it
    c. Determine what must be change to compensate for player height.

Annex – Explanation of projection of wall bottom and top onto screen slice

Games28 Today at 01:46
could you tell me how these variables top_back, bot_back, top_front, bot_front, fDistfrnt, fDistback works. like how you did with the calculatebottomandtop function?
its was super useful

Joseph21 Today at 05:48
Each block in the map has a top and a bottom side, and has a front and back side (it also has a left and right side, but that's not relevant since we are rendering the block in slices) (edited)
These four variables denote the projections of the blocks corner points onto the slice: they are the y coordinates in pixel space:
* `top_back` - the projection (only the y coordinate) of the point at the top and at the back of the block onto the screen slice
* `bot_back` - the same for the point at the bottom and at the back of the block
* `top_front`, `bot_front` - the same but for the points at the top and front resp. at the bottom and front of the block (edited)
Like this:



Joseph21 Today at 05:57

^^ This example show what these variables mean - I drew two player viewpoints and detailed below how the projections on the screen work out:
Looking at viewpoint 1 , the order of these variables along the slice is
1. top_front
2. top_back
3. bot_back
4. bot_front (edited)

Since top_back is projected lower on the screen than top_front, the top side of the block (i also call it the roof) is not visible and must **not** be rendered. The same holds similarly for the ceiling (the bottom side of the block). Along the slice the distance between top_front and bot_front must be rendered with wall texture. (edited)

Now consider viewpoint 2, the order of the variables along the slice is different (since the viewpoint is above the block):
1. top_back
2. top_front
3. bot_back
4. bot_front

The ceiling (bottom face) is still not visible and should not be rendered. However, the top side of the block (aka the roof) is visible, since top_back is higher on the slice than top_front. So part of the slice between top_back and top_front must be rendered with roof texture.
As before, the part between top_front and bot_front must be rendered with wall texture. (edited)

The `fDistFrnt` and `fDistBack` variables contain the distances to the front resp the back of the block, from the players viewpoint. I denoted this in the diagram above. It is used to draw pixels using the depth buffer

Joseph21 Today at 06:10

As an exercise - work out for yourself what the order of these variables would be if the viewpoint is *below* the block, and what that order means for the rendering.