GPU TECHNOLOGY CONFERENCE

S7698:

CanvoX: High-Resolution VR Painting for Large Volumetric Canvas

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http://graphics.ewha.ac.kr/canvox/

VR Painting?


Quill
by
storystudio
Artist : Wesley Allsbrook

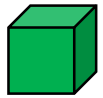

A-PAINTER


Tilt Brush
by Google


PaintLab VR

Fundamental Questions in VR Painting

- Can we recolor, erase, and mix the color?
- Can we draw and mix transparent object?
- How much can we extend canvas?
- How detail can we draw?
- How can we navigate 3D canvas?



Voxels?

Challenges

- Large Canvas with high detail
  - Deep Level Octree
    - Expensive refinement and coarsening
  - Dynamic Tree on GPU
    - Random access → need complex data structure
    - CPU-GPU transfer cost
- Rendering
  - Real-time ray casting (resolution $1680 \times 1512 \times 2$, 90fps~)
    - Tree traversal time
  - Accumulated error along the ray

CanvoX Model

HMD

- View
- Position

Controller /Haptic Device

- Brush Position

CPU

Octree

Parent ID

Child ID

flag

RGBA

Temp0

Stroke Data

Stroke ID

Segment ID

Main Thread

Initialize Octree

Update view matrix & controller pos.

Render

Store stroke data

Update texture block to GPU

Paint Thread

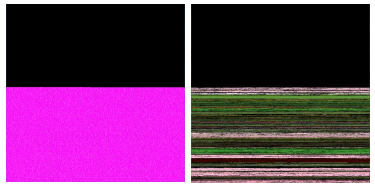
Color and mark cell

One-level refine/coarsen marked cell

Update Block Ordered Set

block ID

Octree



GPU

Update 3-neighbor texture

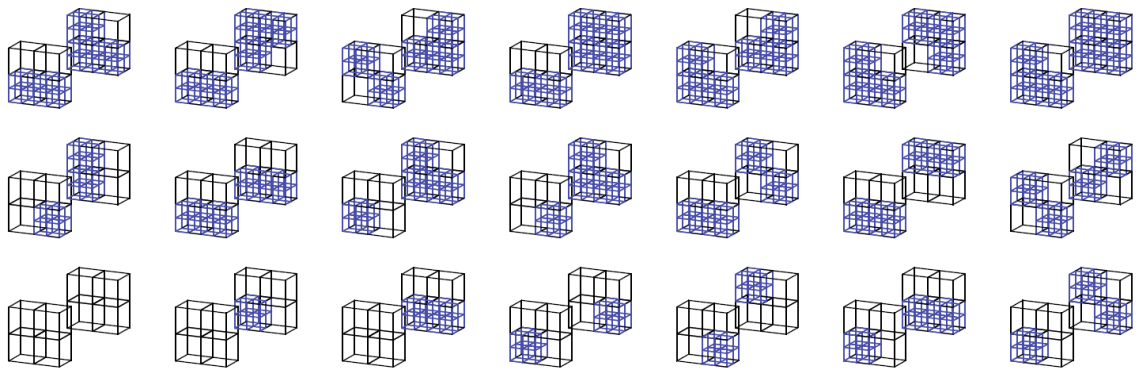
Render heat map

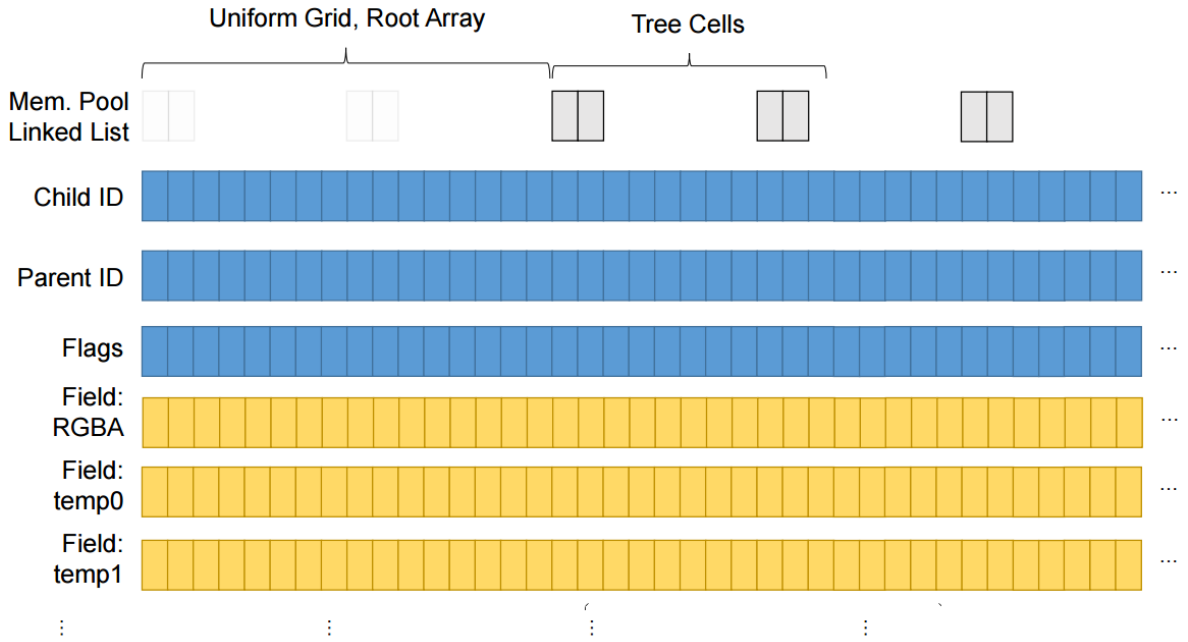
Render Scene(Ray Casting)

Update Scene Quad Tree

Interpolate Scene Quad Tree

CPU Side Octree



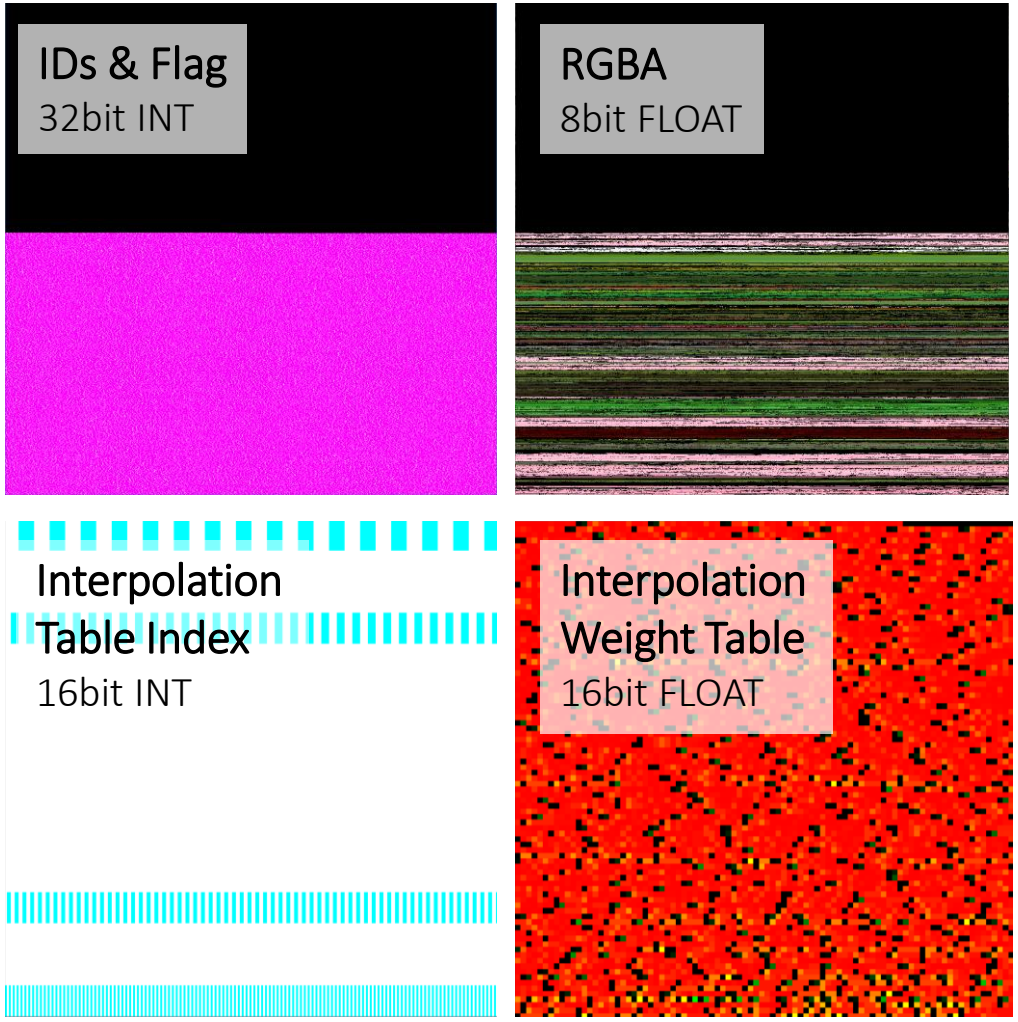


- Strong 2-to-1 Balanced Tree [Kim15]
  - Root array(Uniform grid) + Tree
  - Simple primal-only tree
  - Maximum depth level : 26
  - Physical Unit : $0.3\mathrm{mm}^3 \sim 40km^3$

- Each cell has
  - Parent ID
  - Child #0 ID
  - Flags – depth, refine, coarsen, etc. …
  - RGBA

[Kim15] Byungmoon Kim, Panagiotis Tsiotras, Jeong-Mo Hong , and Oh-young Song,
Interpolation and parallel adjustment of center-sampled trees with new balancing constraints

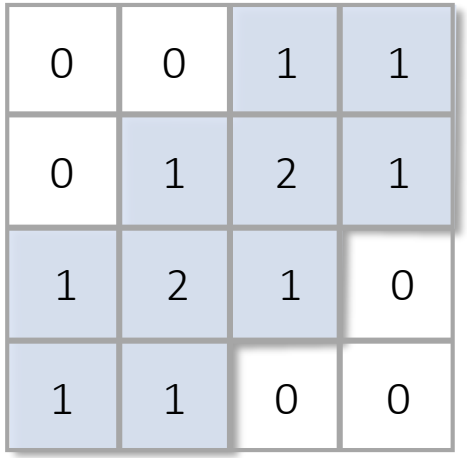
GPU Side Octree



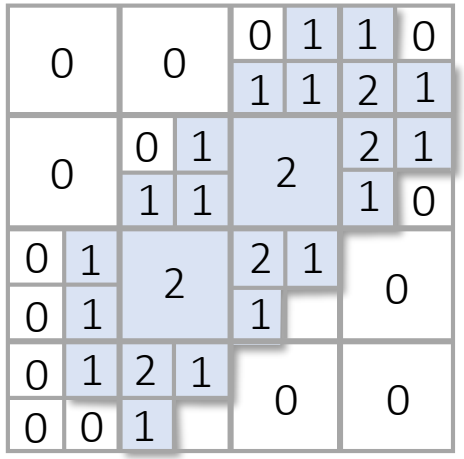
- GPU has shadow octree of CPU octree
  - Memory management benefits from CPU
  - Convert 1D Array Fields → 2D Array Texture
  - Size of texture image : 30MB
- Only updates **blocks** of texture
  - Block : $M \times N$ Texels
  - Brush causes only local changes with tree
  - Tree Index is located on same texel regardless of cell

Refinement and Coarsening

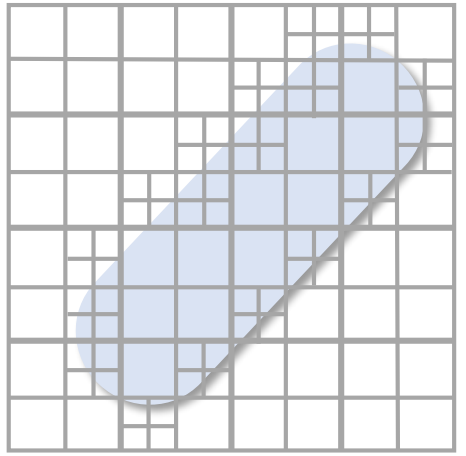
0 : outside
1 : boundary
2 : inside



Frame t_0



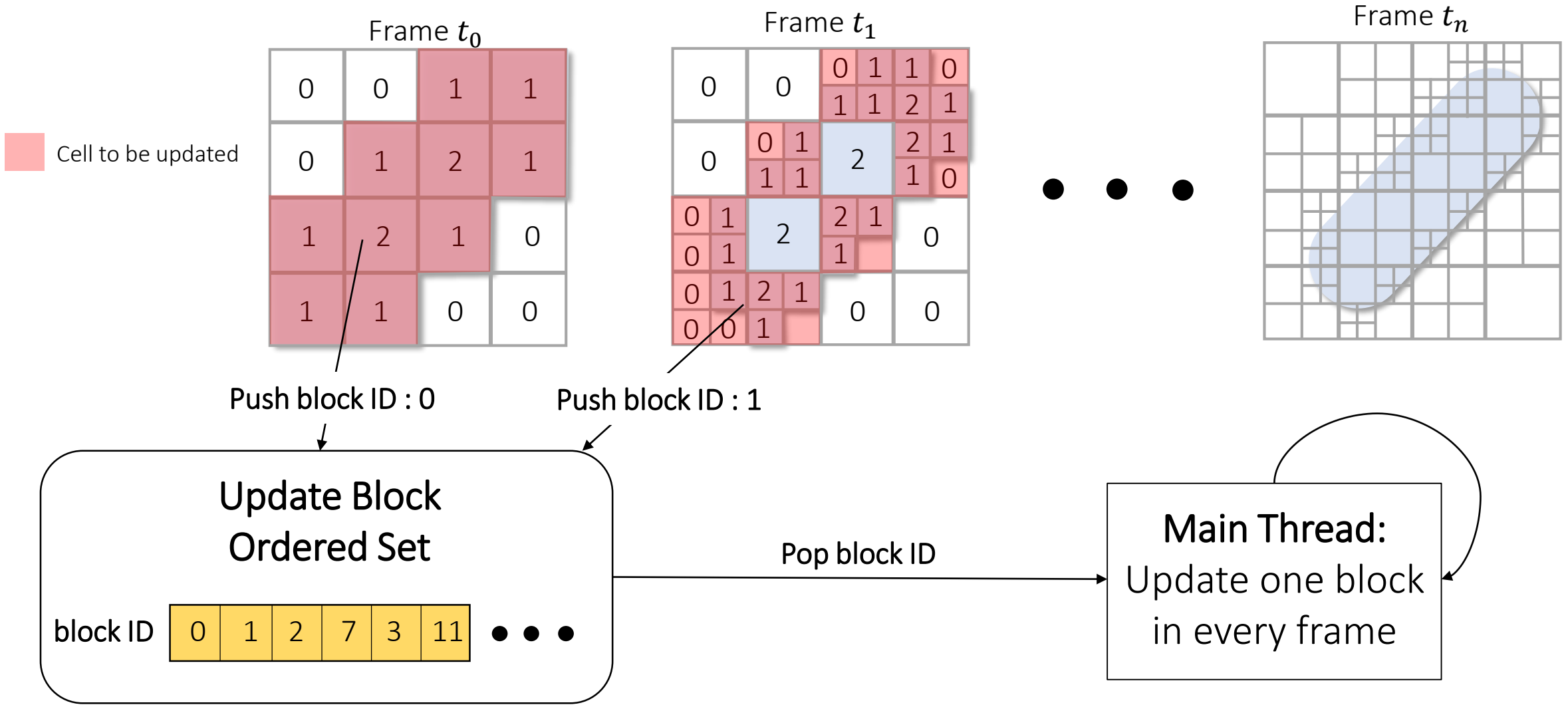
Frame t_1

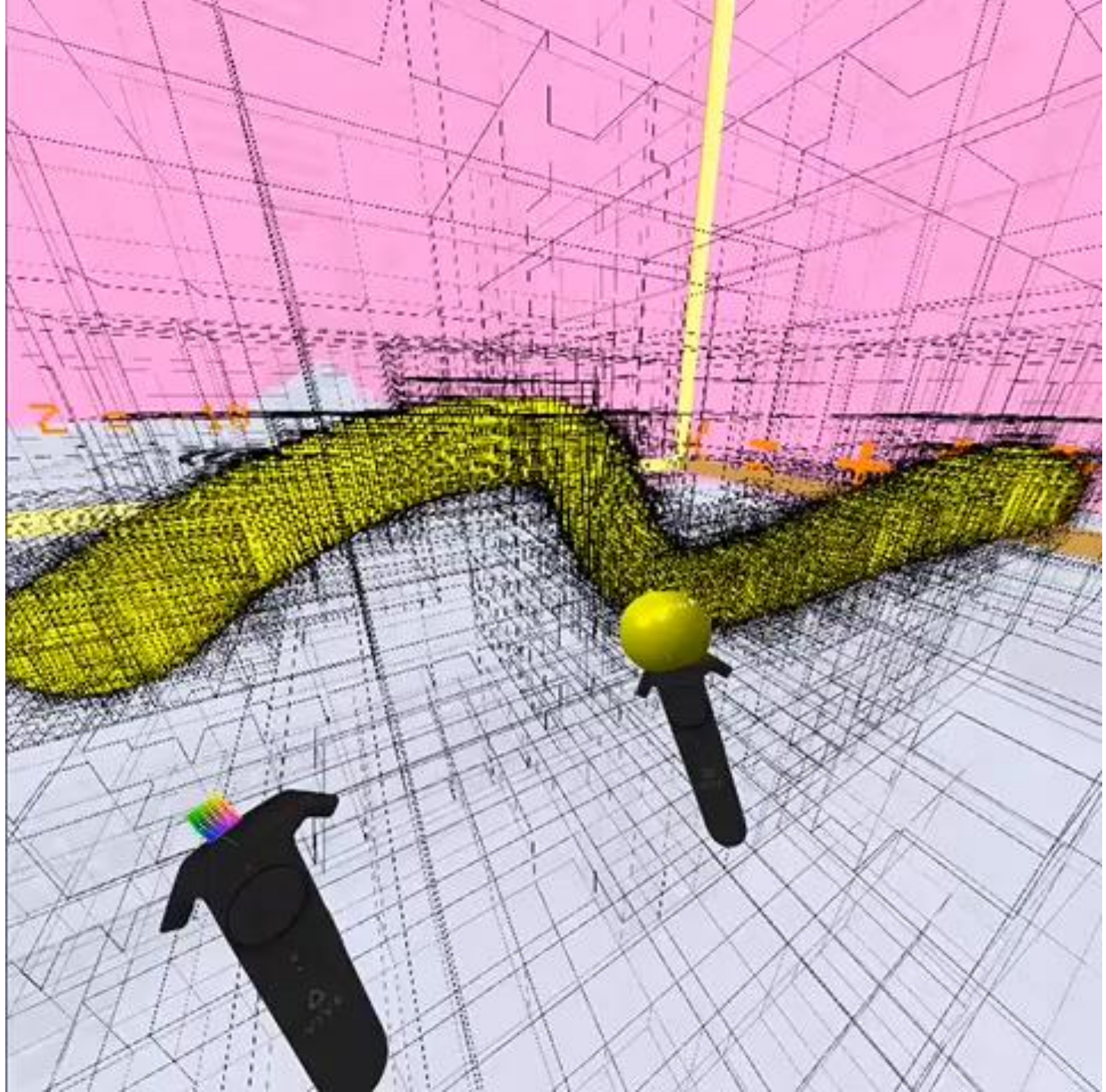


Frame t_n

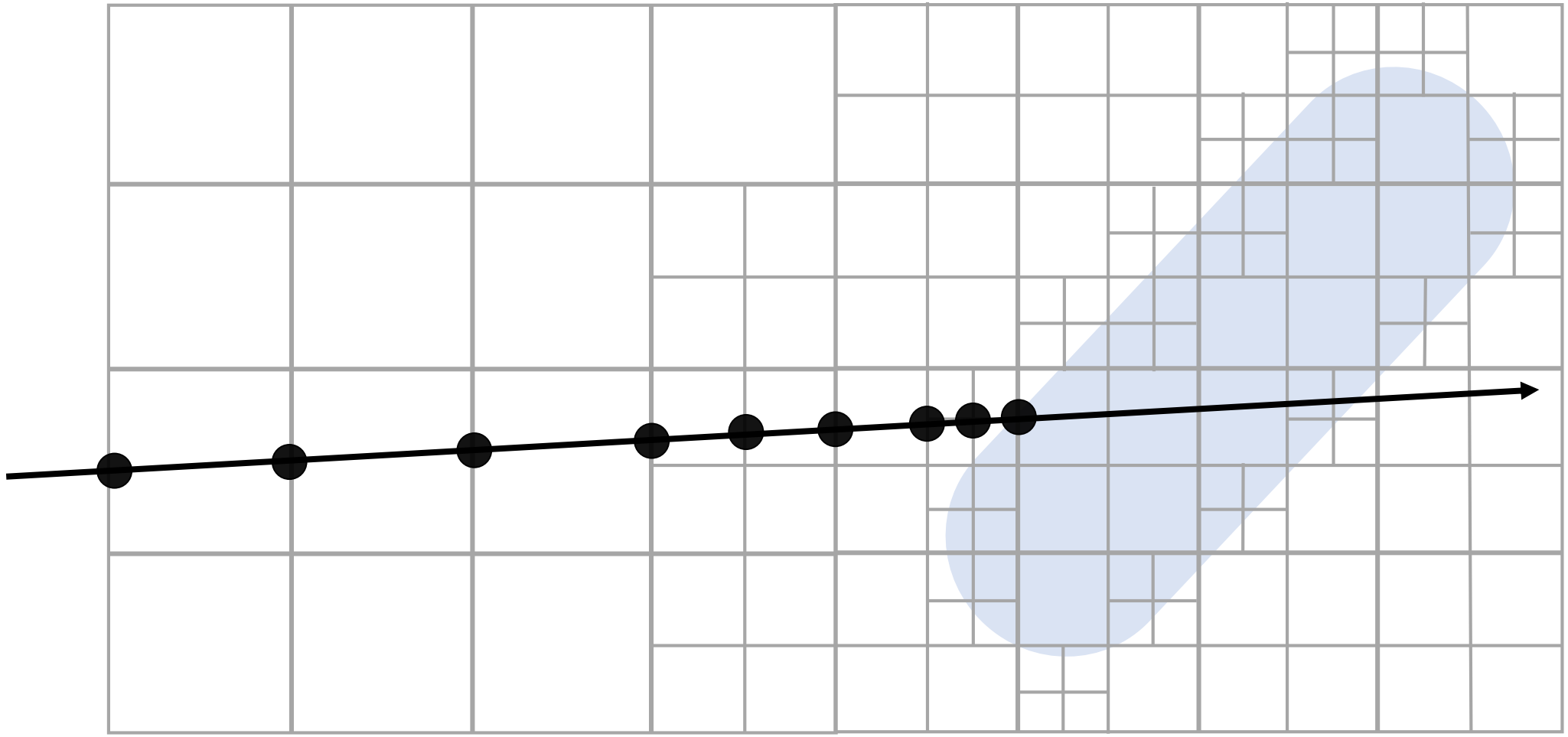
- At each frame, do only **one-level** refinement/coarsening
- Refinement/Coarsening will finished less than **#Max Depth frames**
- While tree traversal, color the cells and find cells to be refined simultaneously
- “Outside” cell helps to reduce tree traversal cost

… and Update Tree on GPU

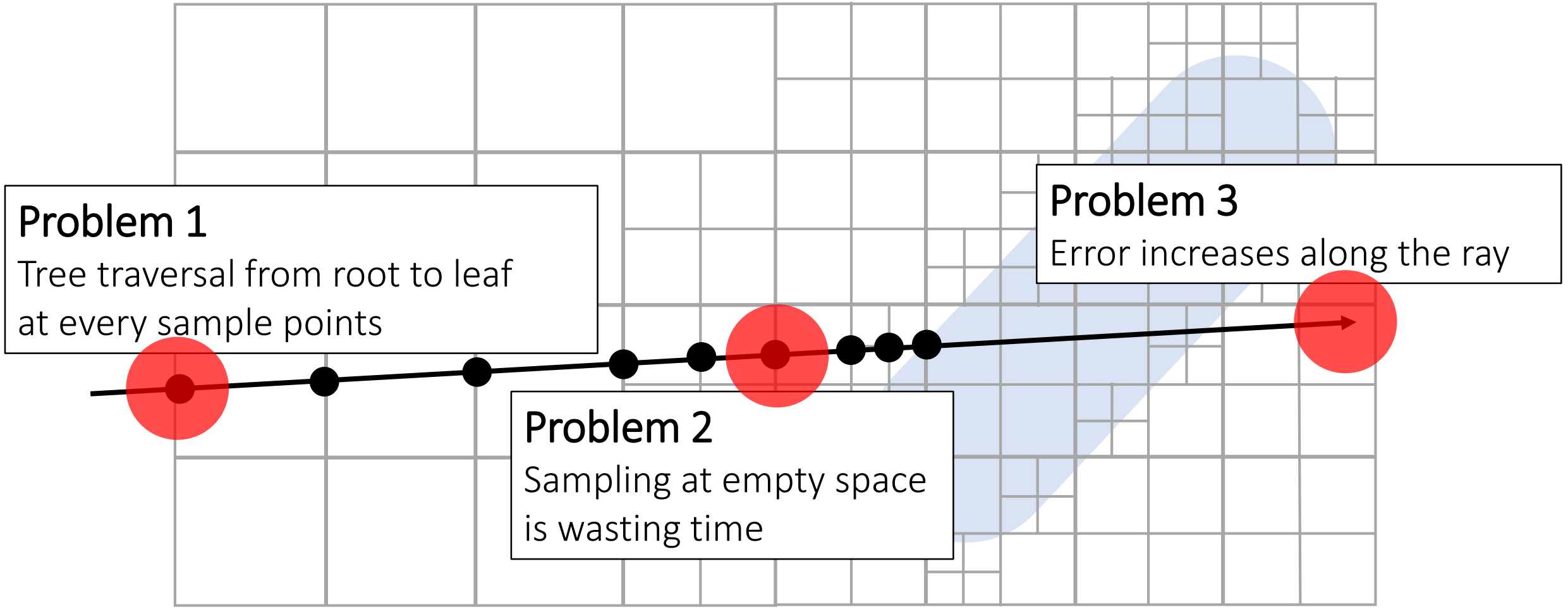




Ray Casting in Large Canvas



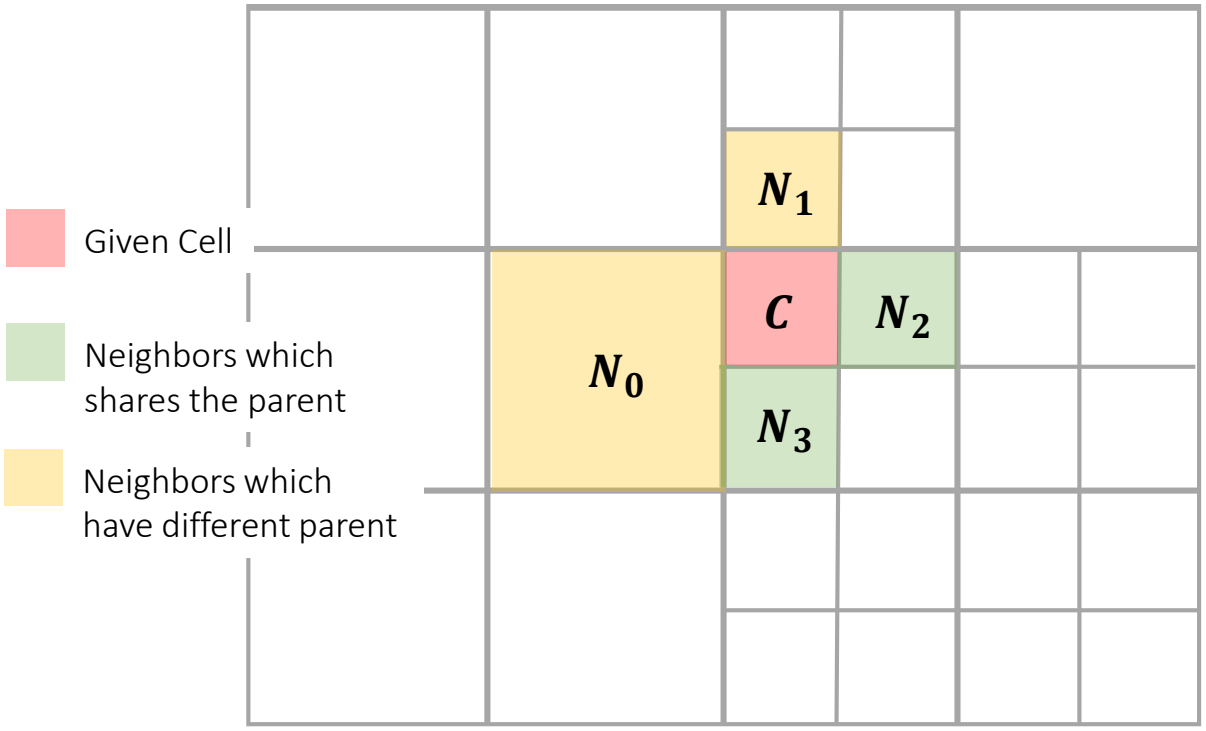
Ray Casting in Large Canvas



Octree : 3-Neighbors

- Tree traversal from root to leaf at every sample points

→ **Tree traversal using neighbor cells with ray direction**



- Thanks to strong 2-to-1 balance tree,
  - A cell always has 6 neighbors
  - 3 neighbors share the parent (= Their ID can be computed by using offset)
  - 3 neighbors have different parent

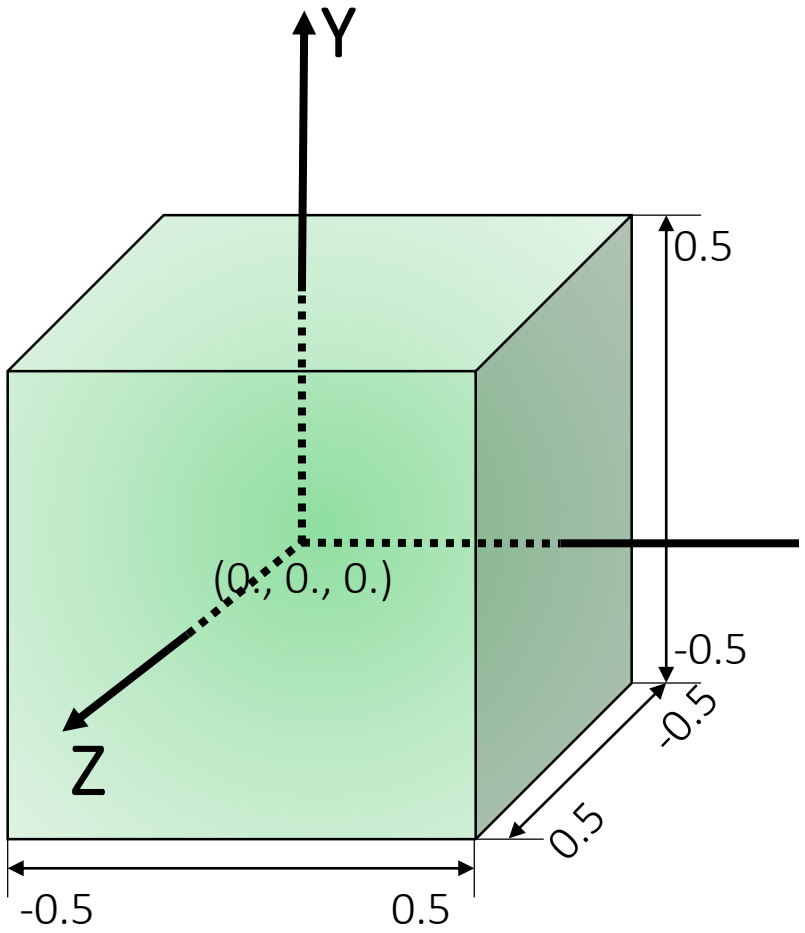
→ **If we precompute only 3 Neighbors, we can move to next neighbor directly**

It’s not so far……..

Using World Coordinate System

Using Local Coordinate System

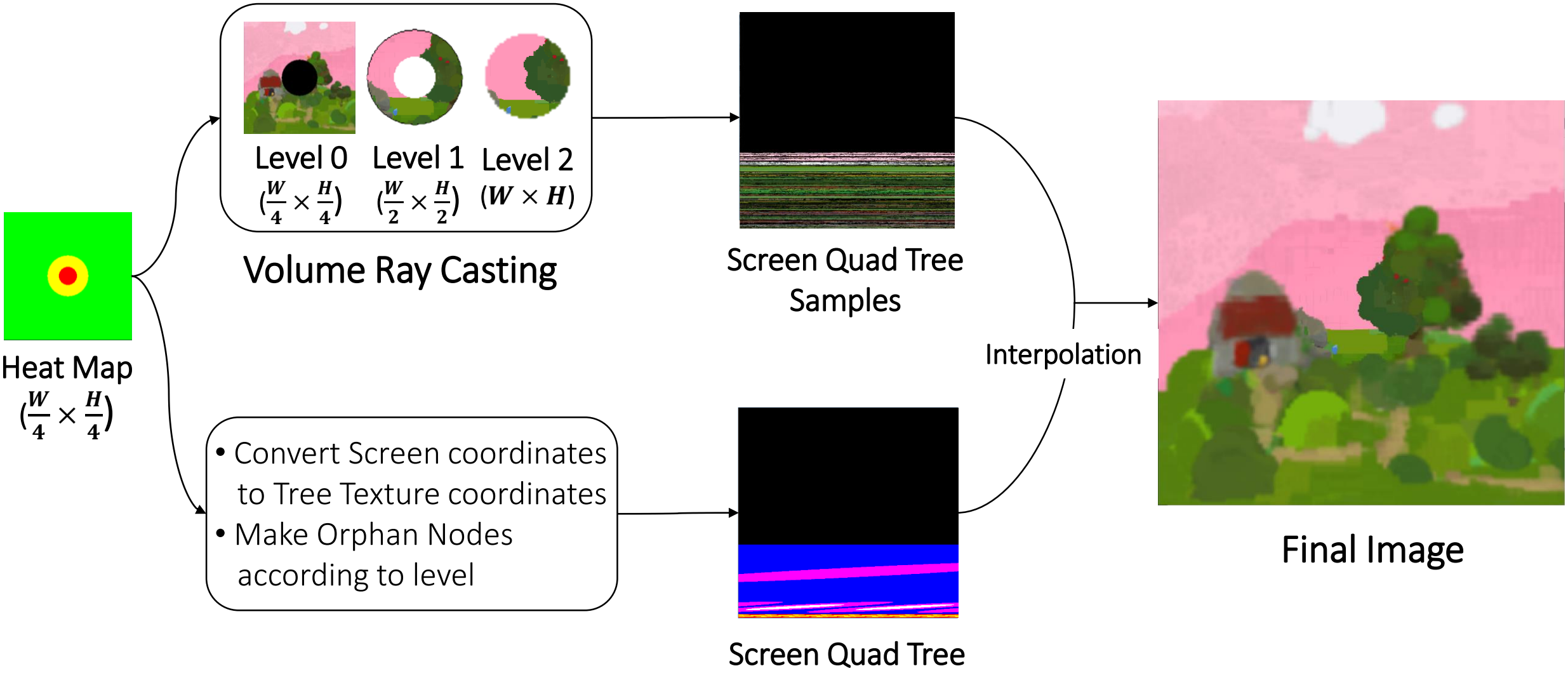
Ray Casting with Local Coordinates




```
vec3 rayCastWithLocalCoord(in vec3  rayDir,
                           in float rayMaxLength,
                           in uint  initCellID,
                           in vec3  initRelativeVec)
{
    posCellID = initCellID;
    posRelVec = initRelativeVec;

    while(rayLength <= rayMaxLength)
    {
        //find neighbor cell
        (nbDir, minDist) = rayBoxIntersection(rayDir, posRelVec)
         neighborID      = getNextNeighbor(posCellID, neighborDir)
         rayLength      += minDist*cellWidth;

         if(cellHasColor)
             colorSum = blendColor(colorVolume);

        //update current cell and relative vector
        posCellID = neighborID;
        posRelVec = computeRelativeVectorInNextFrame(posRelVec);
}}
```

Foveated Rendering

With Screen resolution $\boldsymbol{W} \times \boldsymbol{H}$,



Summary

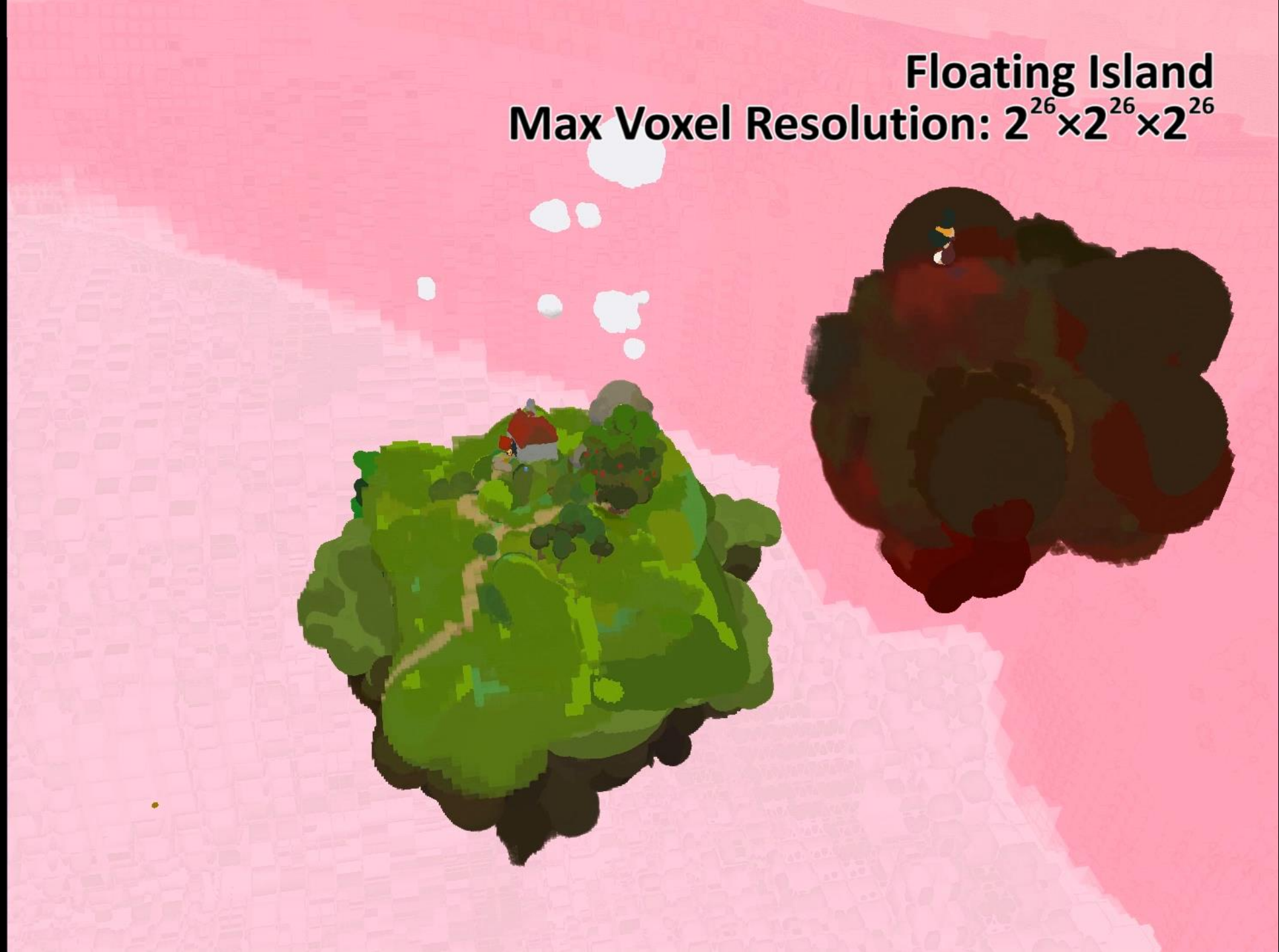
- Dynamic and Simple Octree both on CPU and GPU
  - Shadow octree on GPU and local updates
  - One-level refine/coarsen strategy

- Ray Casting in Large Canvas
  - 3-neighbor and ray casting with local coordinates
  - Foveated Rendering

- Future work
  - Performance optimization
  - Improve assistive tools
  - Isosurface Rendering


Paint Mode

result


Floating Island
Max Voxel Resolution: $2^{26} \times 2^{26} \times 2^{26}$

Thank you ☺

Ack. :

Project Webpage : http://graphics.ewha.ac.kr/canvox/

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