Screen-Space Triangulation for Interactive Point Rendering

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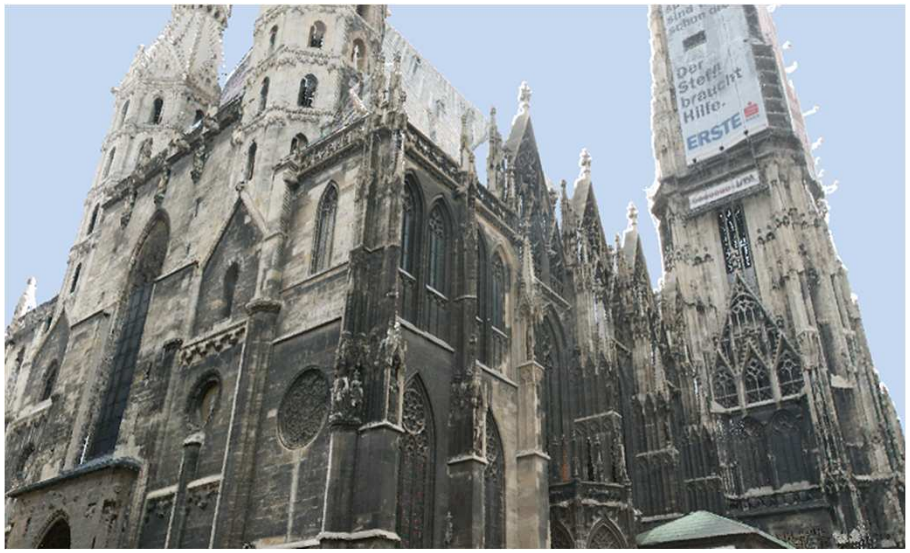
Motivation

- High-quality point rendering mostly implies some kind of continuous surface reconstruction

- Using Point Properties for rendering
    - point normals (local surface orientation)
    - splat radii (connectivity)

Motivation

- Huge point clouds: time-consuming Preprocessing



- St. Stephans Cathedral
  460 Million Points
  Normal Est.: ***~ 17h***

  Domitilla Catacomb
  1.9 Billion Points
  Normal Est.: ***~ 21h***

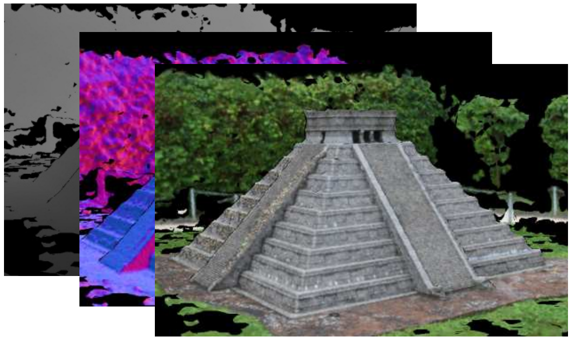
Motivation

- Can we achieve comparable quality on rendering without precomputed attributes?
- → **Our Approach:** Reconstruct normal and connectivity info **on-the-fly** during rendering in **screen-space** on the **GPU**
- **Advantages**
  - No time-consuming preprocessing
  - Saves memory for storing attributes (normals, radii)
  - Rendering/Reconstruction independent from data layout (Hierarchical, Out-Of-Core, …)
- **Possible Applications**
  - Fast on-site preview of scanned point clouds
  - Instant rendering of 4D point streams

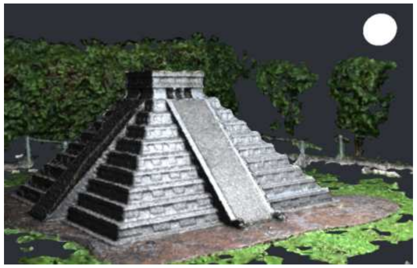
Overview of Our Approach

- Input: Point data projected to screen
  - Position
  - Color (optional)

- Output: Reconstructed frame buffers
  - Depth
  - Normal
  - Color (optional)

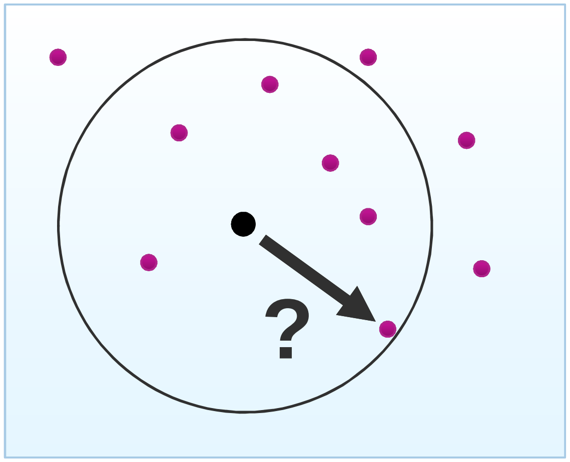


- Use for further deferred shading, illumination, …



Surface reconstruction - FAQ

- Given a surface sample → which neighbors to use for reconstruction?
  - KNN, FDN, …
  - robust statistics, LMS …



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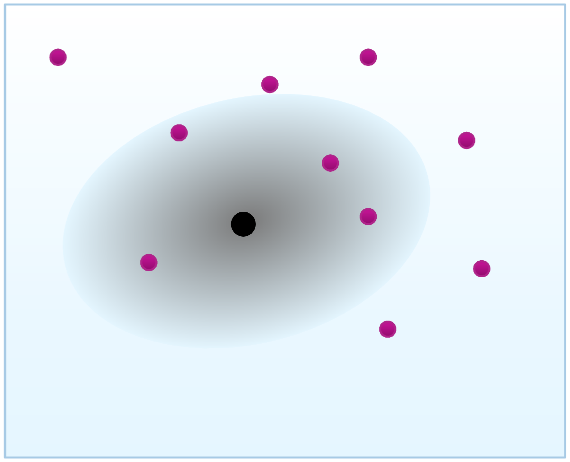


- Given a local neighborhood → how to reconstruct surface?
  - surface fitting, forward search, …

Surface reconstruction - Our Approach

- Given a surface sample → which neighbors to use for reconstruction?
  - KNN, FDN, …
  - robust statistics, LMS …

  → **Screen-Space Nearest Neighbor Search**

- Given a local neighborhood → how to reconstruct surface?
  - surface fitting, forward search, …

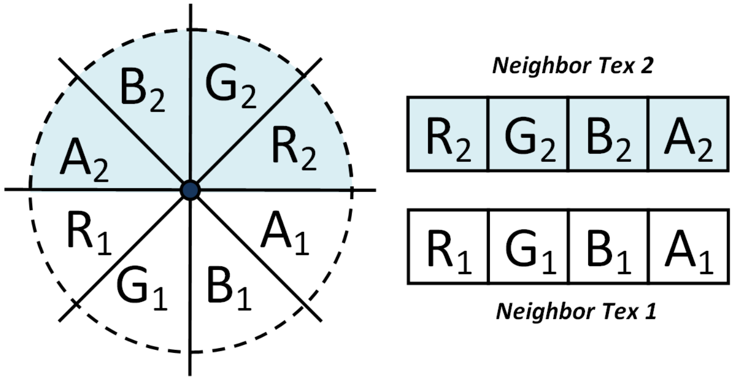
  → **Normal Estimation & Triangulation**

→ Screen-Space Nearest Neighbor Search

- Input:
  - projected point buffer
  - Initial search radius ***r***

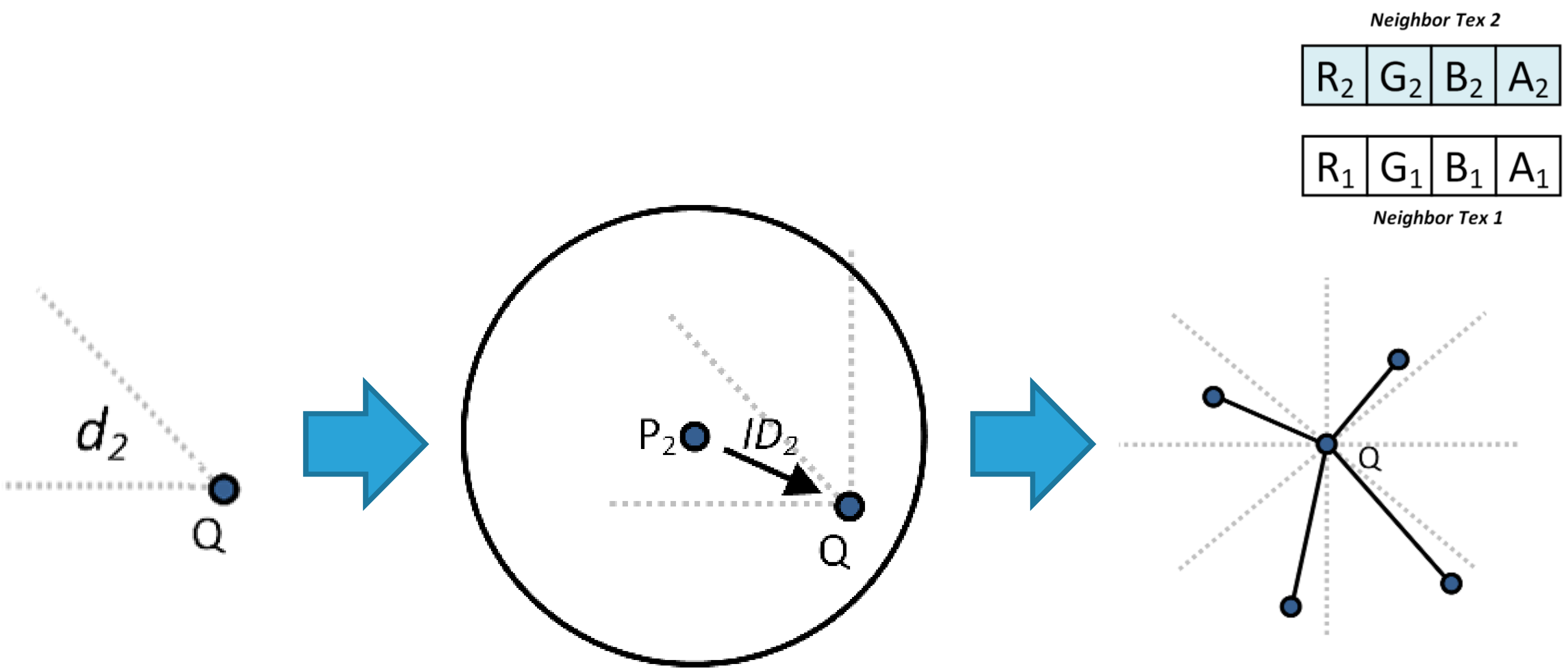
- How to quickly ***find*** and ***store*** k nearest neighbors of each point ***Q*** in the input buffer?

- Divide screen space region around ***Q*** *in **8 segments***
- Storing nearest neighbor of each segment in 2 RGBA Textures

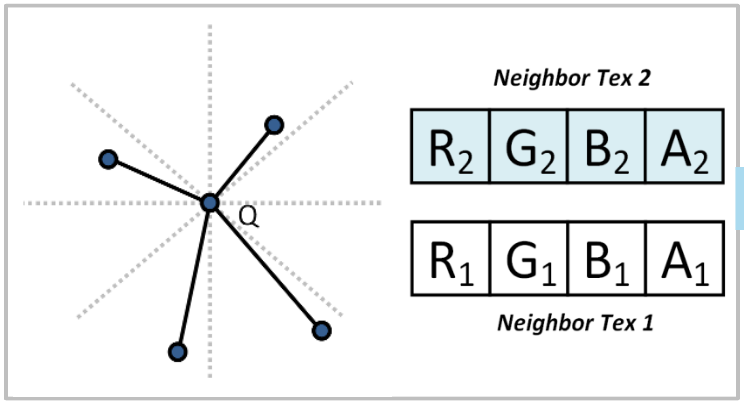


→ Screen-Space Nearest Neighbor Search

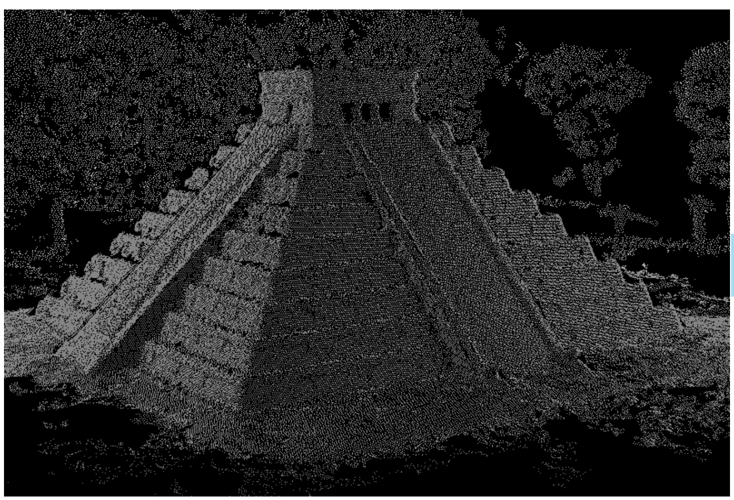
- Pass 1: for each P_i, render search splat of radius ***r***
  - Store min. world space distances d_{min} at pixel Q
- Pass 2: Render Search Splats P_i again
  - Compare distance P_iQ with saved d_{min}



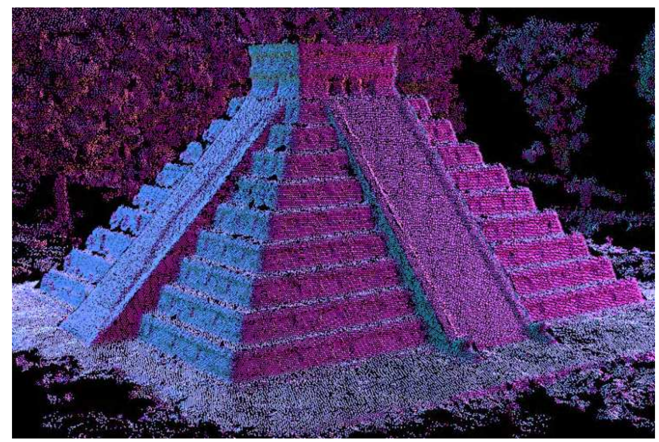
- Lookup the neighbor points and calculate normal



Neighbor Buffers



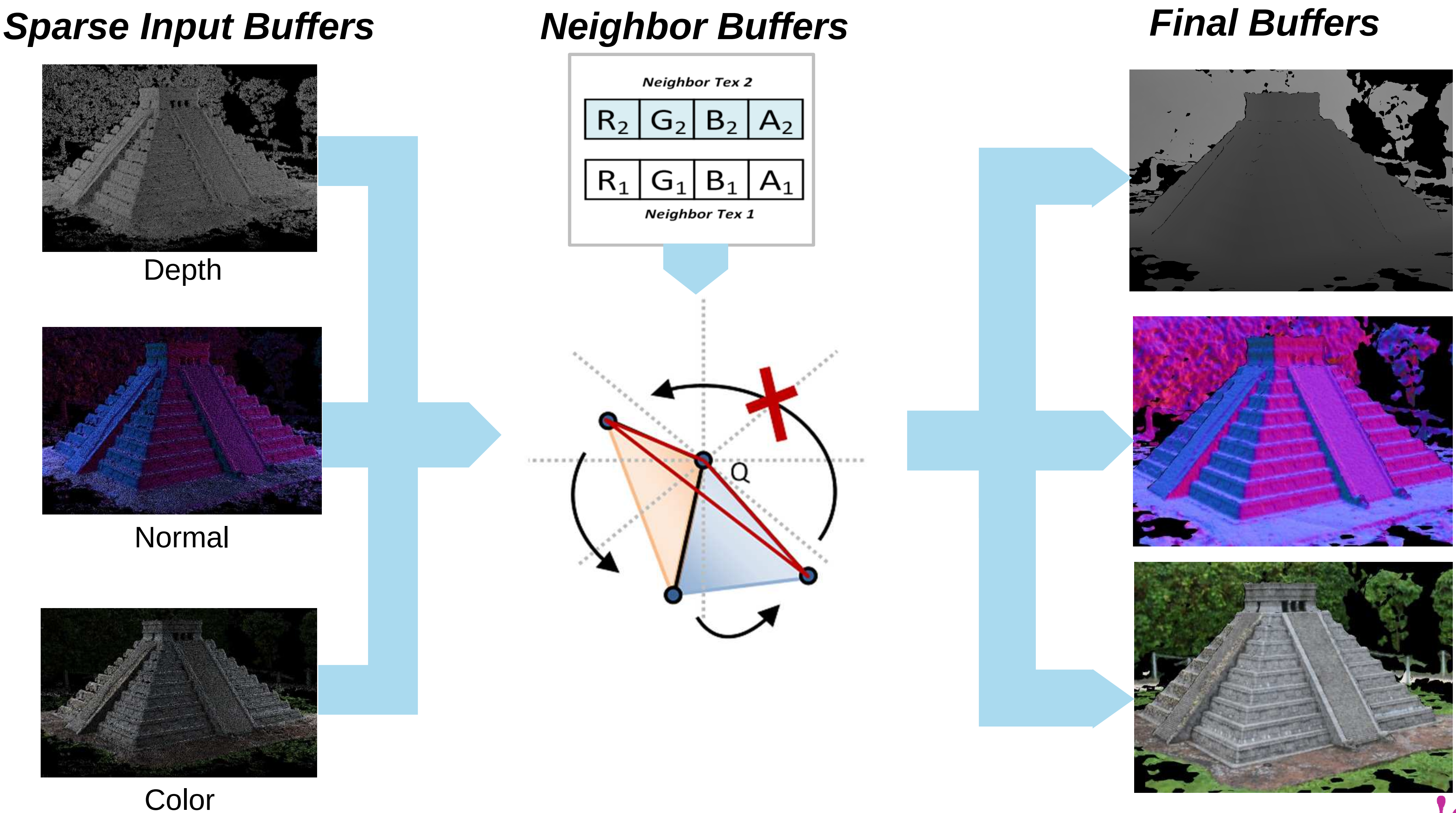
Point Position Buffer



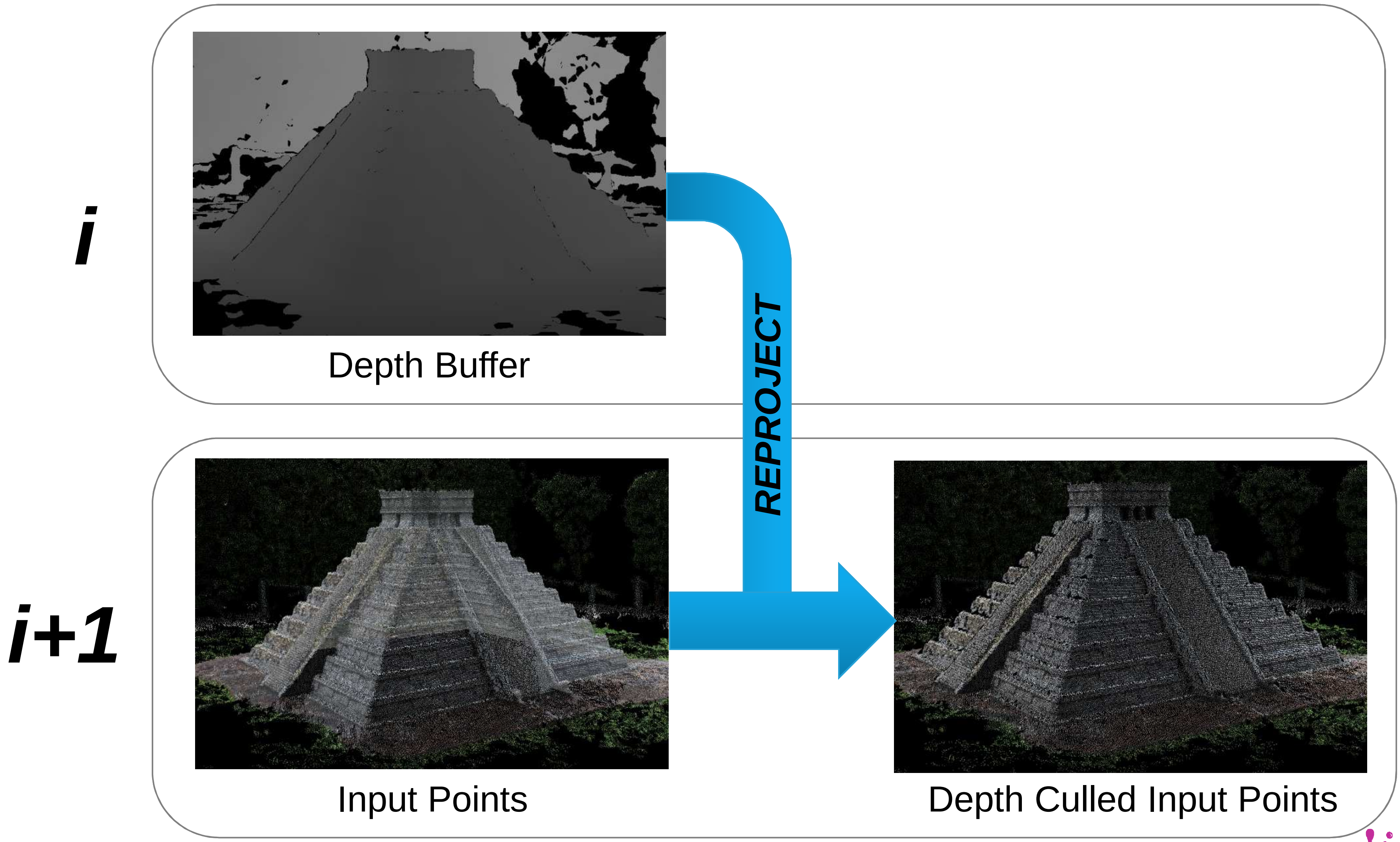
Point Normal Buffer

→ Triangulation

- Triangulation in Geometry Shader

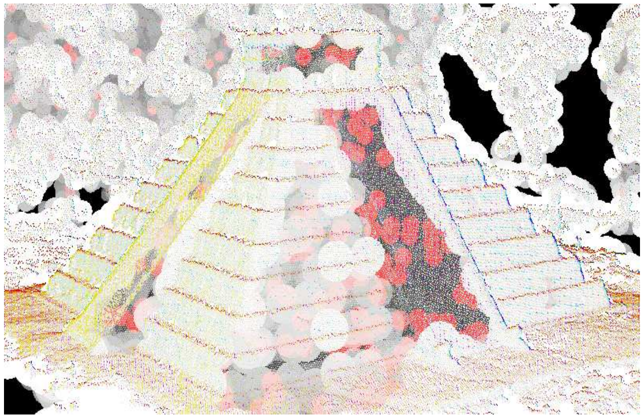


Temporal Coherence Depth Culling



Search Radii

- Maintain a search radius buffer
- Adapt radii over time
- Start with initial search radius r_0
- Define increase factor $\alpha > 1$



- Frame i:

  if #neighbors too small (e.g. < 3)

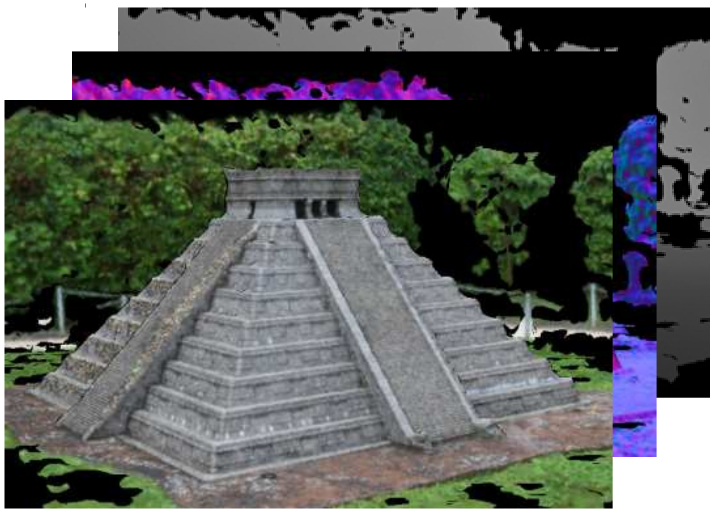
  $r_{i+1} = r_i * \alpha$

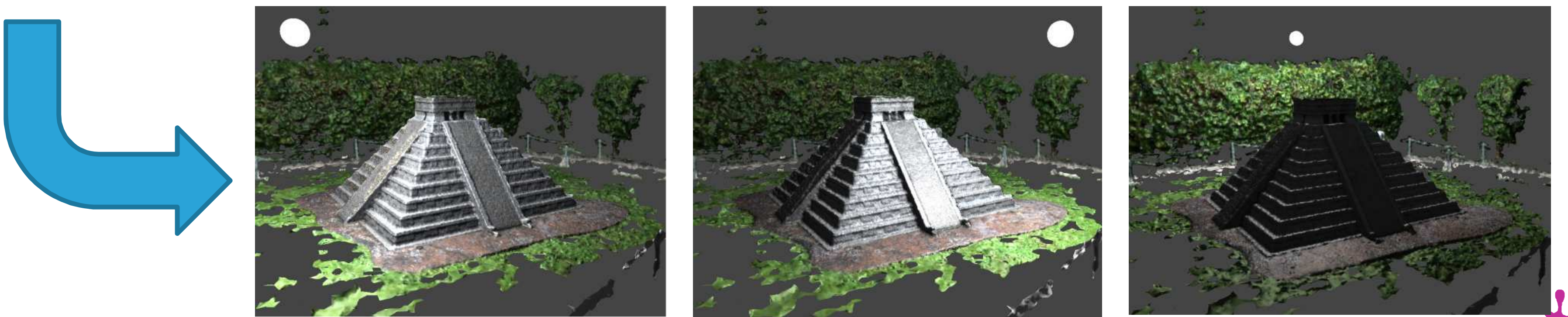
  else

  $r_{i+1} = \max(\text{distance}(\text{neighbor}_k)),\ k = 1 \ldots 8$

Algorithm - Summary

1) Project points to screen
   - Depth cull with depth buffer from previous frame
2) Update search radii
3) Perform neighbor search
4) Normal estimation
5) Triangulation





Results

Comparison to point splatting

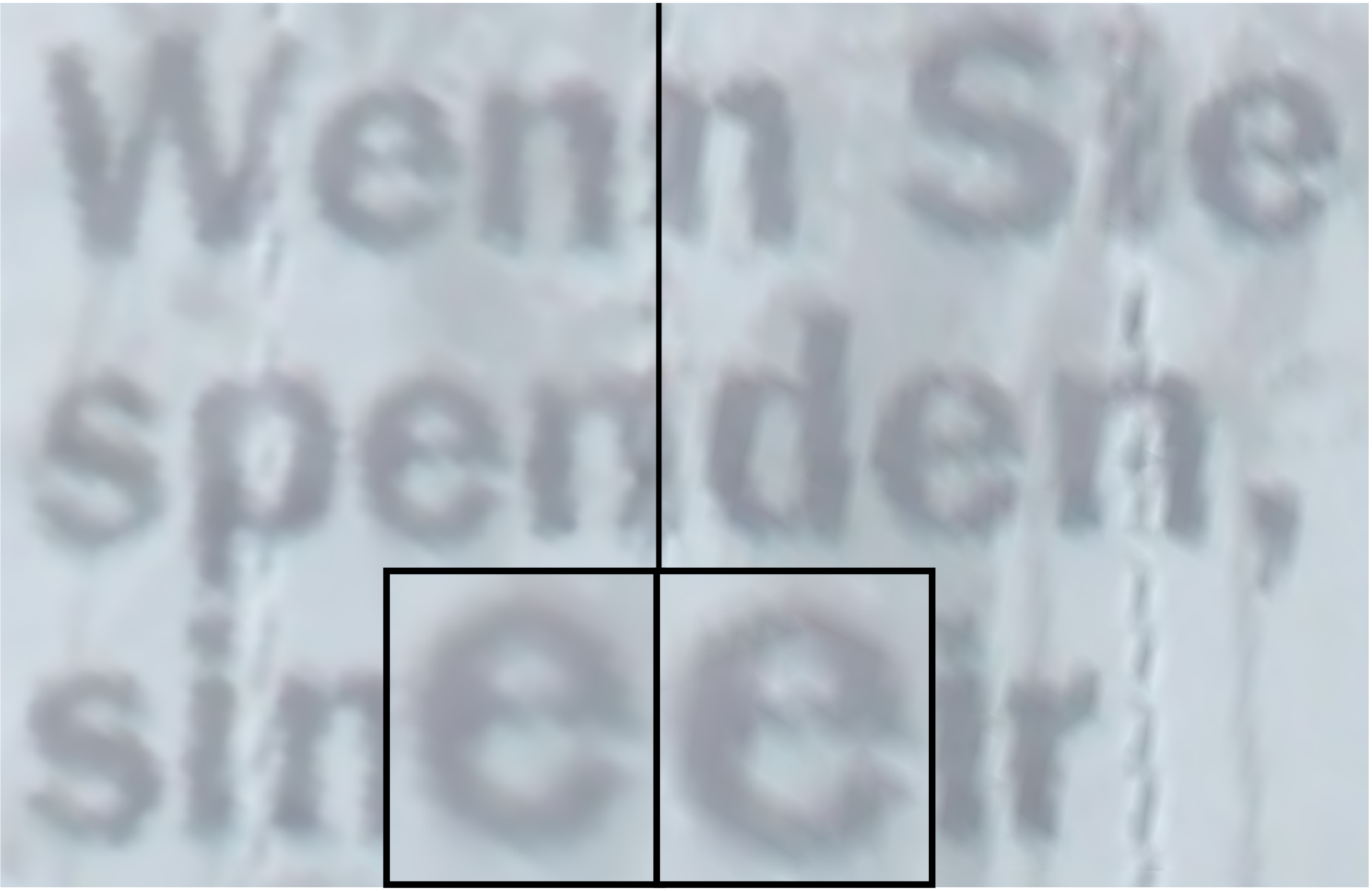
Box Splatting

Gauss Splatting

SST

Results

Gauss Splats (Precomputed) SST

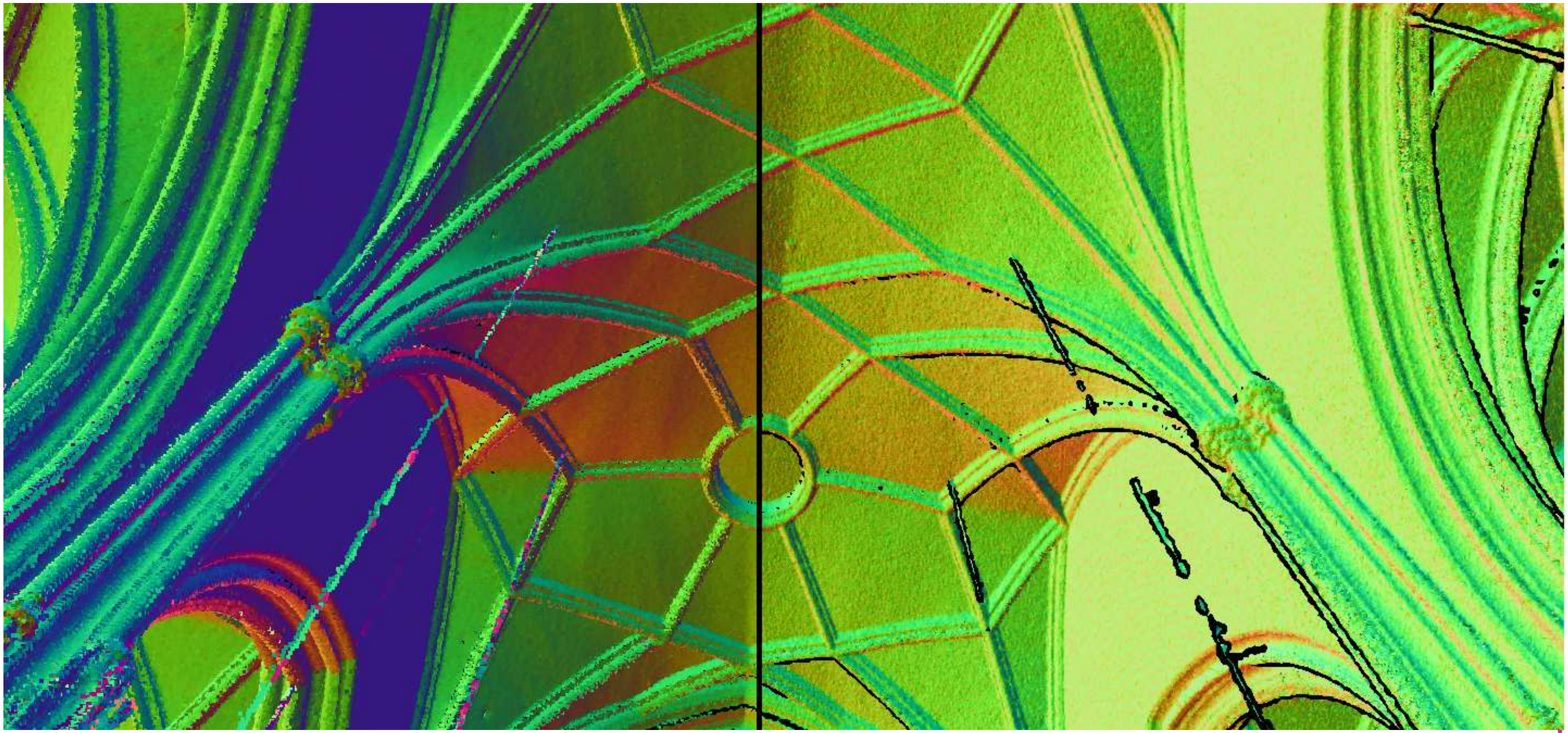


Results

Normalestimation only locally → noise sensitive

precomputed Normals

SST Normals



Conclusion / Outlook

- Interactive rendering without precomputation
- Quality comparable to Gauss splats

- **Drawbacks**
  - Temporal Coherence Artifacts, Flickering
  - Some degrees of freedom (r_0, α)
  - Normal estimation only local

- **Future Work**
  - Introduce denoising of normals by geometry-aware filter
  - Estimate absolute radii per frame (get rid of TC, r_0 and α)
  - → instantly estimate good splat radii → Gauss splatting?