1001 Acquisition Viewpoints

Efficient and Versatile View-Dependent Modeling of Real-World Scenes

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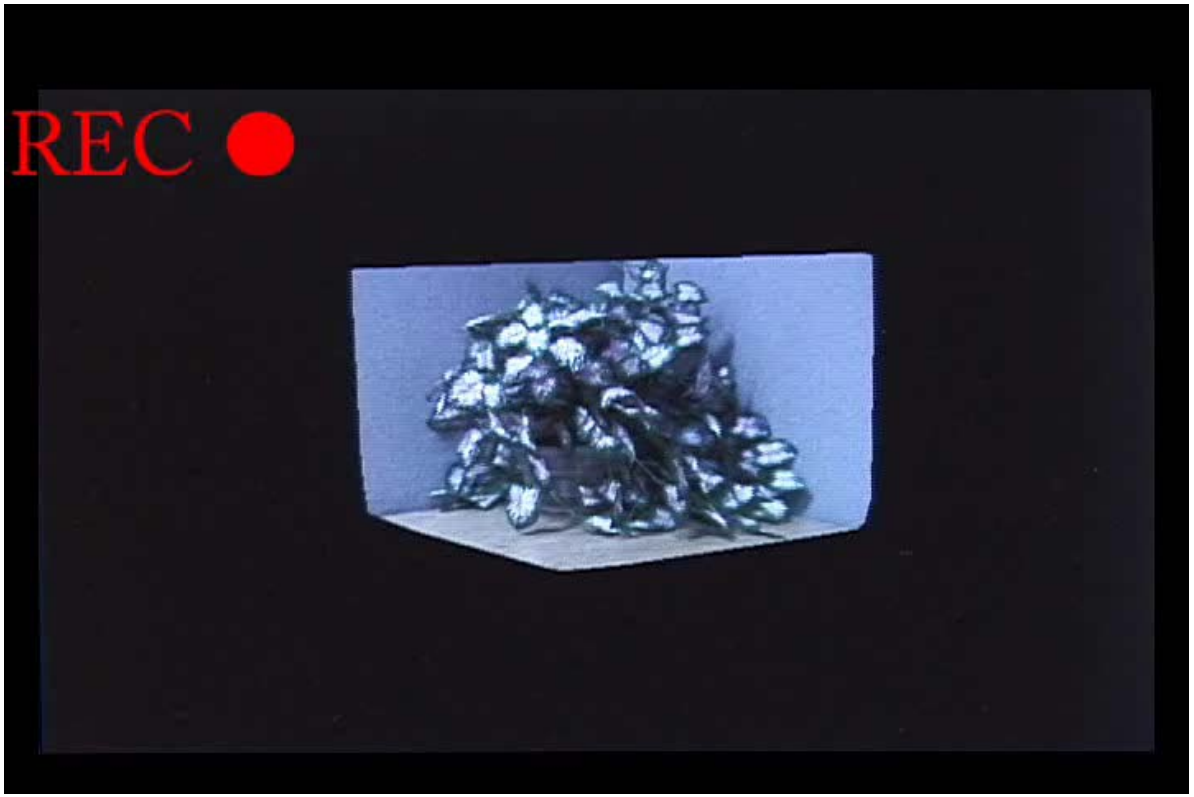
3D Modeling

- Severe bottleneck for computer graphics applications
- Manual modeling
  - Time consuming
  - Fails to capture the complexity of real-world scenes
- Automated modeling
  - Promising alternative
  - No complete solution yet

Results preview



Rendering of a plant model acquired in 10 minutes with our automated modeling system.

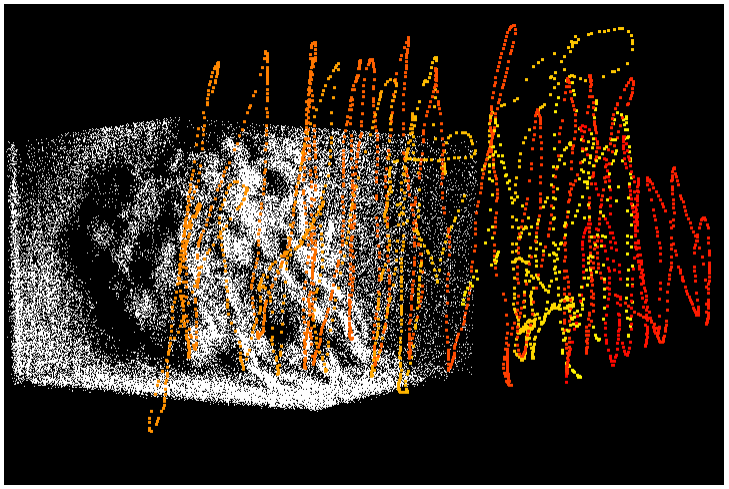
Prior work—DDSV

- DDSV : dense depth/sparse viewpoints
  - Classical modeling approach
  - Scene scanned densely from a few locations
- Shortcomings :
  - Poor scene coverage
  - High data redundancy

Prior work—ray databases

- Examples
  - Panoramas (2D)
    - Do not allow translations
  - Light fields, lumigraphs (4D)
    - Do not scale well with scene size
- No support quantitative applications

Our approach—SDDV



- Sparse depth/dense viewpoints (SDDV)
  - Scene sampled sparsely from thousands of acquisition viewpoints
- Advantages
  - Sparse depth acquisition efficient and robust
  - Operator in the loop, interactive modeling
  - Compact photorealistic model, w/ geometry

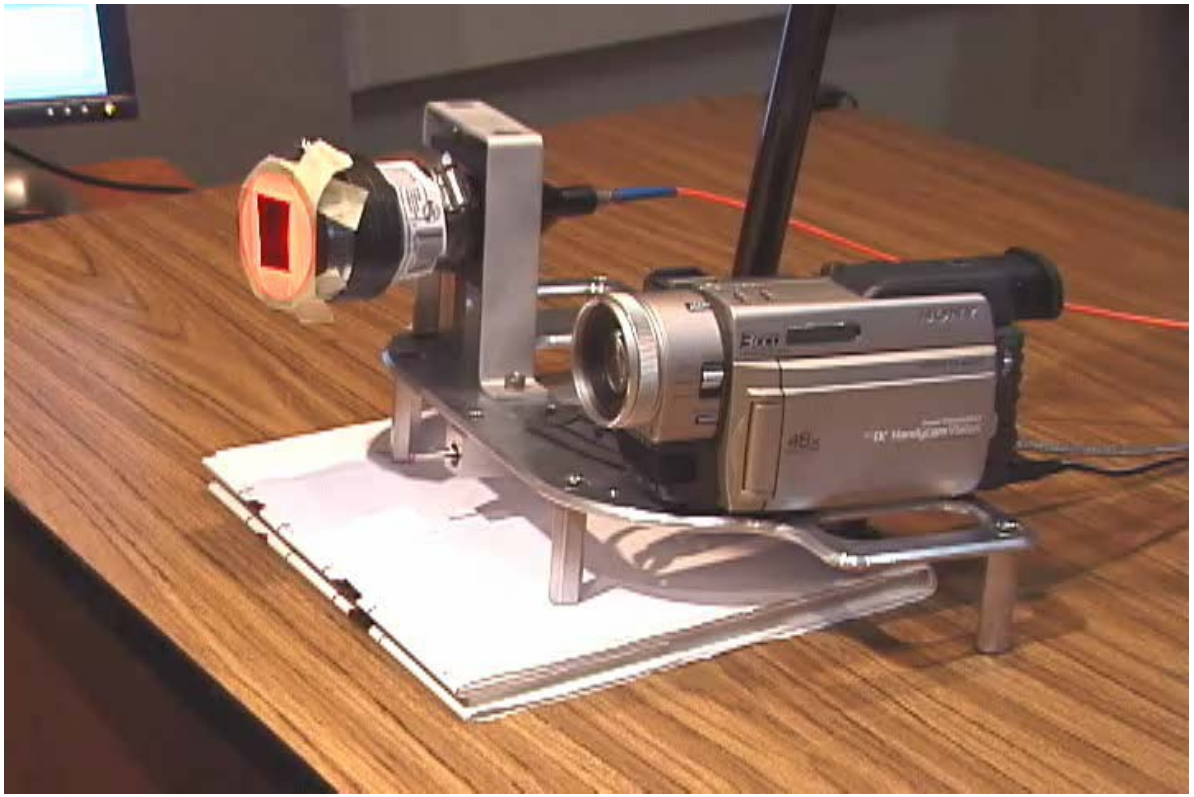
Overview

- Acquisition device
- Depth Acquisition
- Color Acquisition
- Rendering

Design requirements

- To implement SDDV, the acquisition device should :
  - acquire sparse depth efficiently and robustly
  - acquire high-quality color
  - allow the operator to freely position the acquisition device
  - provide real-time feedback during acquisition

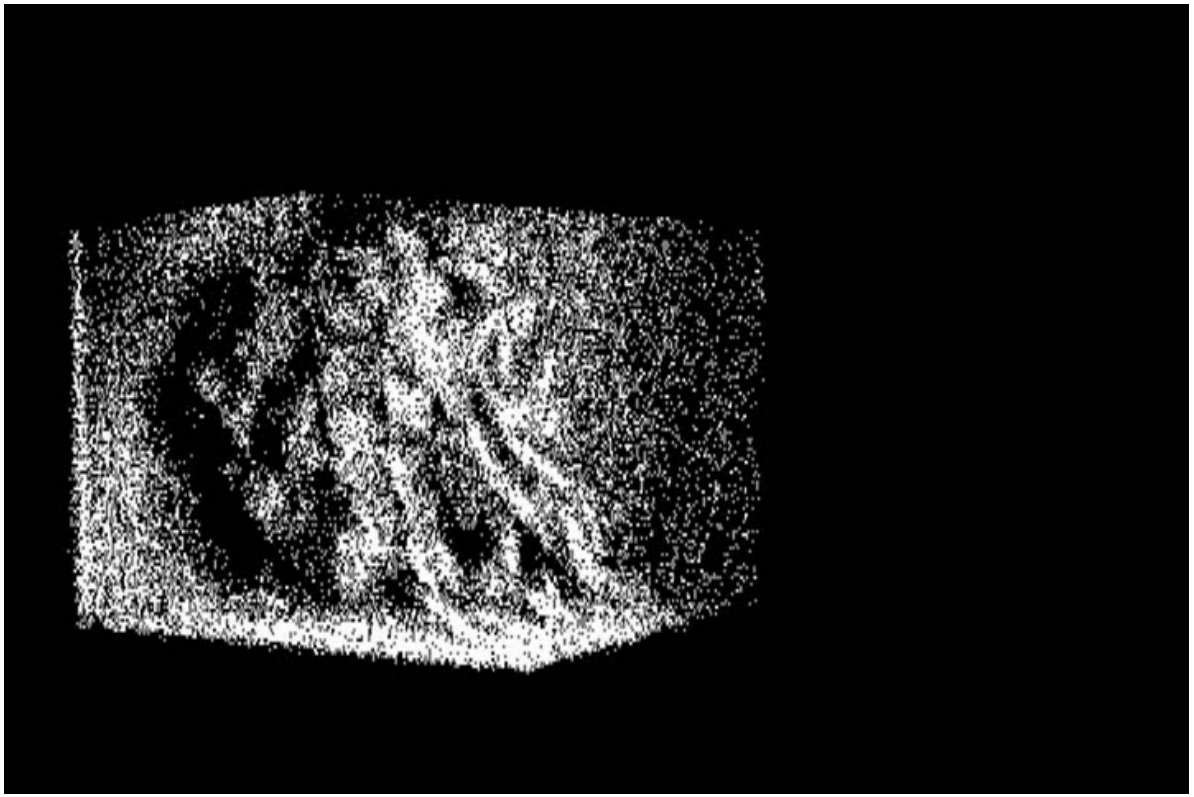
Acquisition device overview



Acquisition device

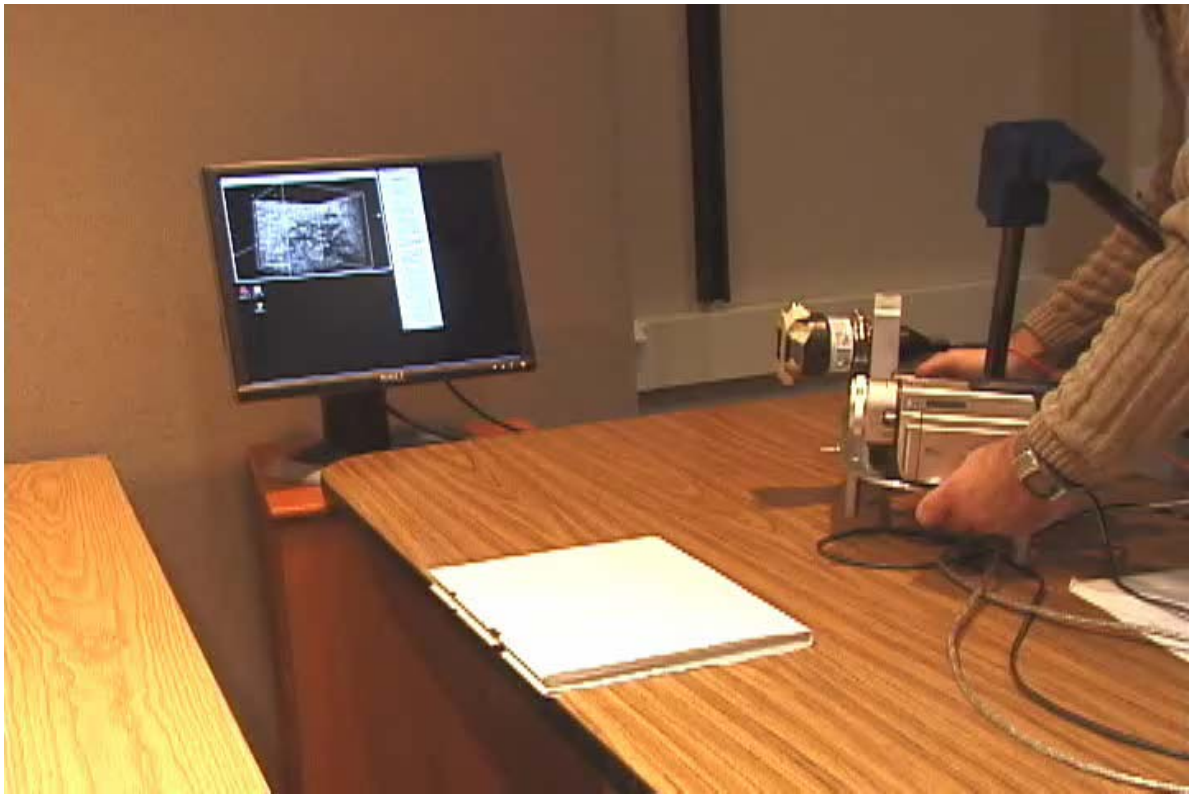
Depth Acquisition

Depth Acquisition

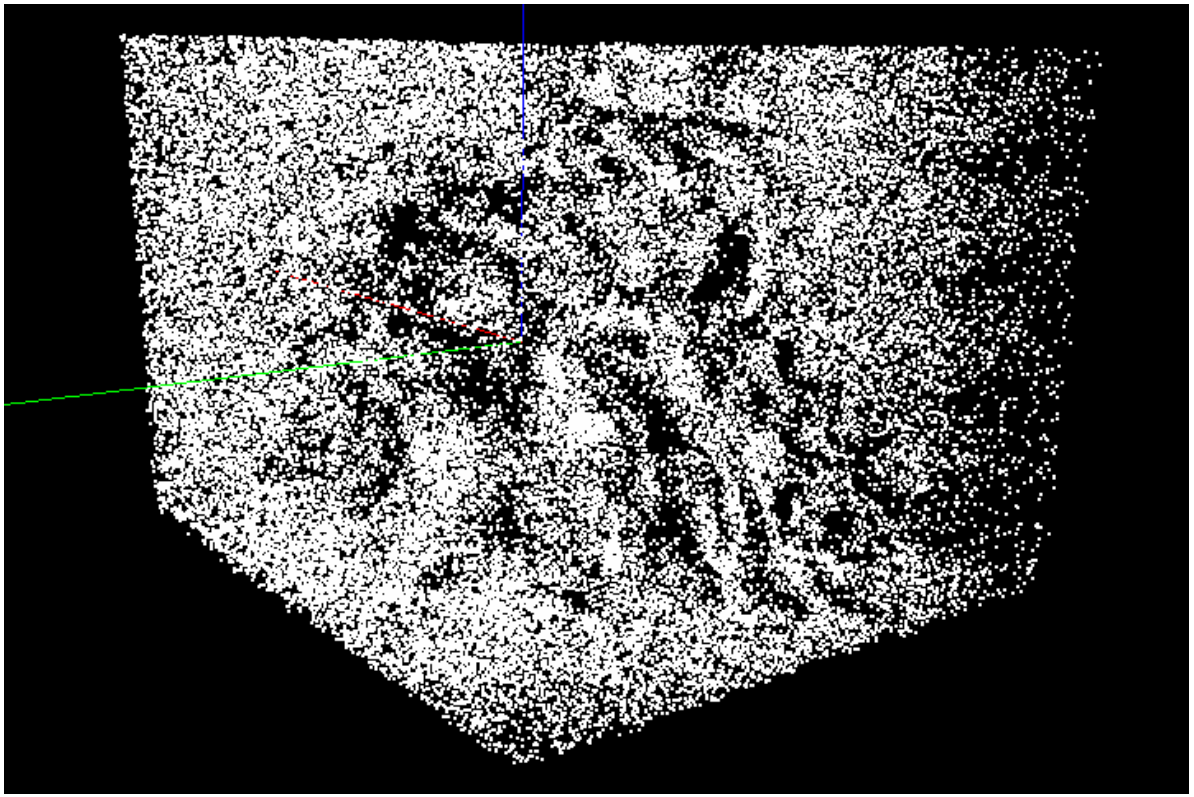


Typical acquisition path

Color acquisition

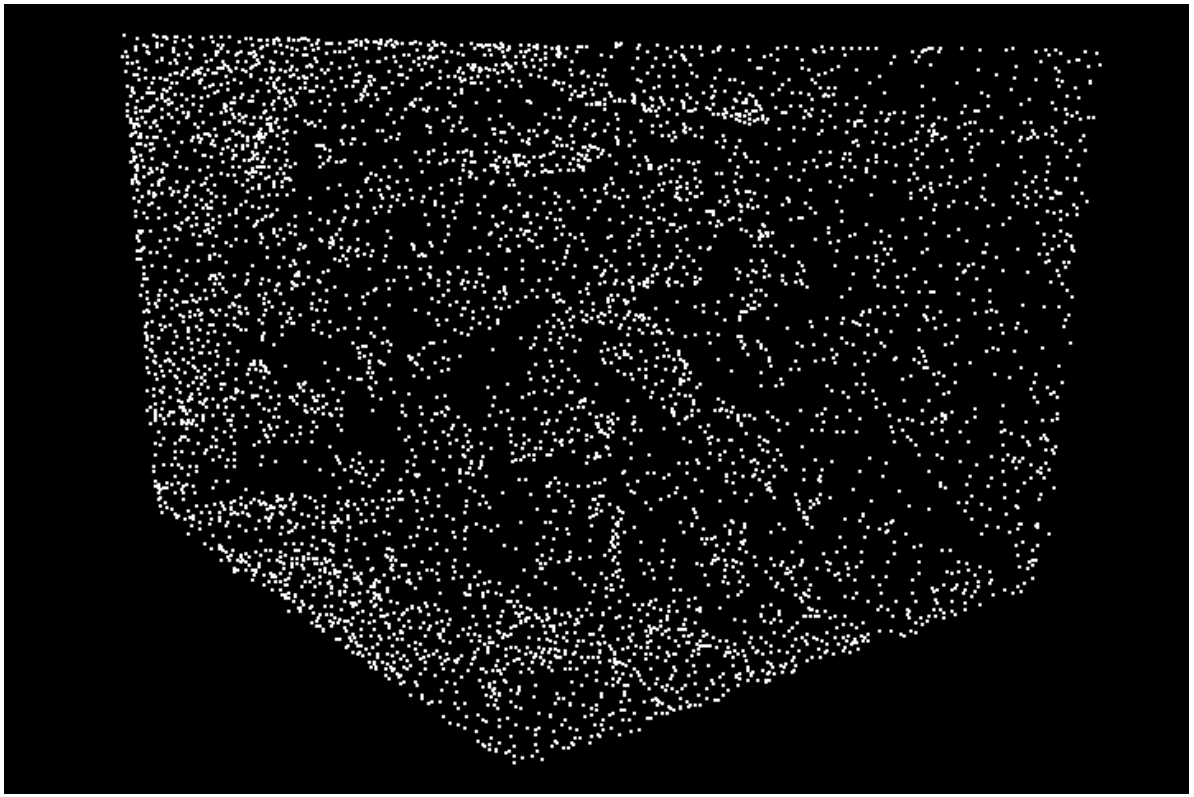


Rendering algorithm



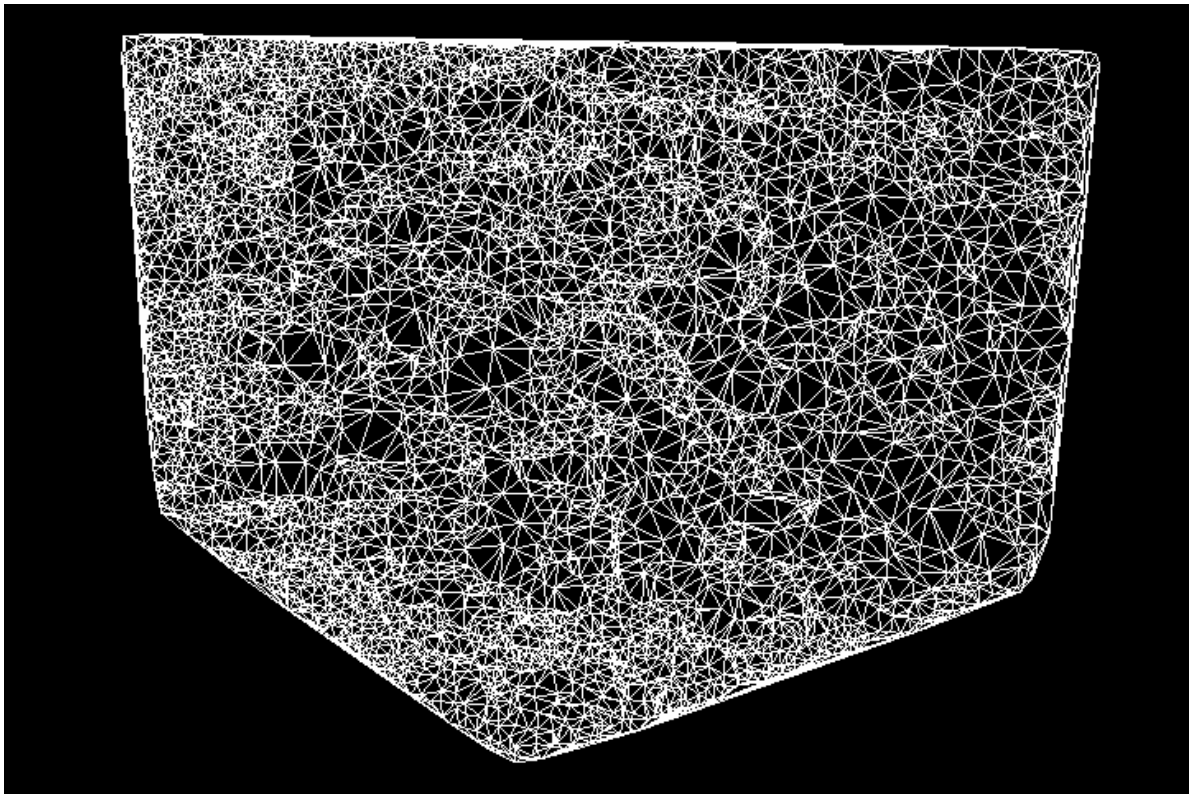
View-dependent modeling

Rendering algorithm



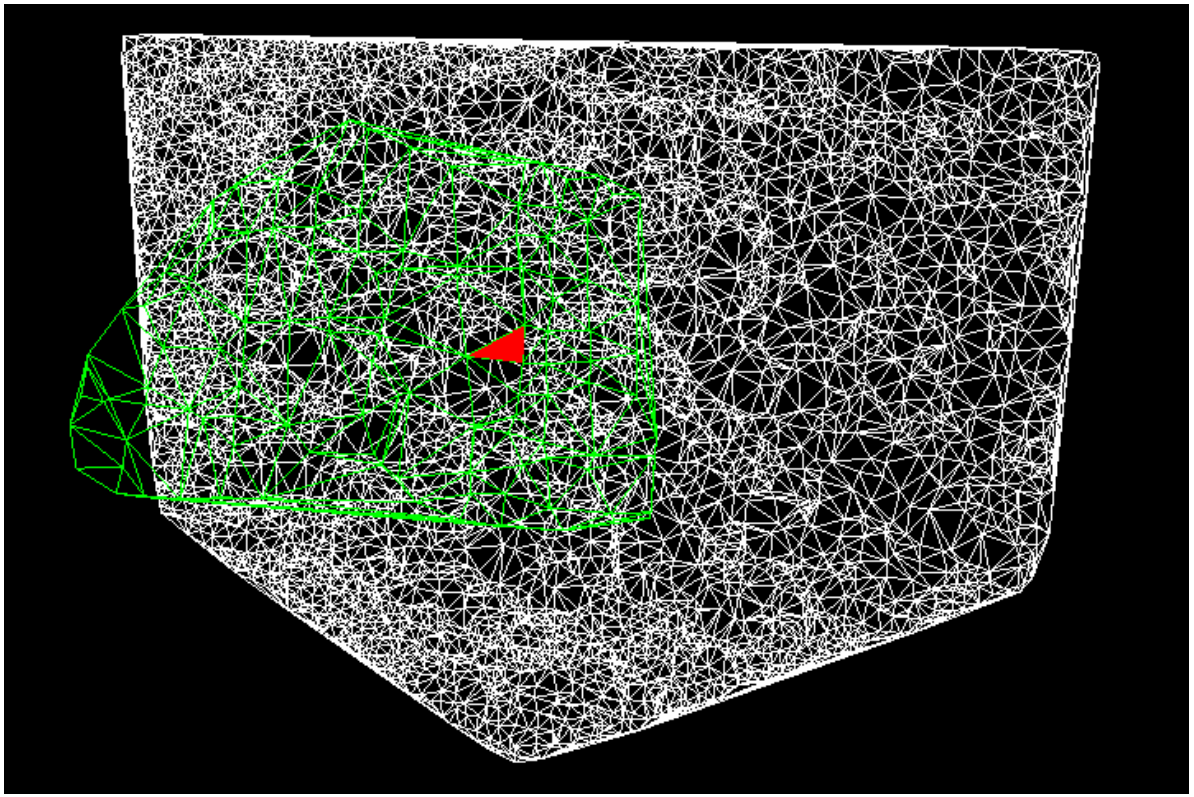
Compute visible points

Rendering algorithm



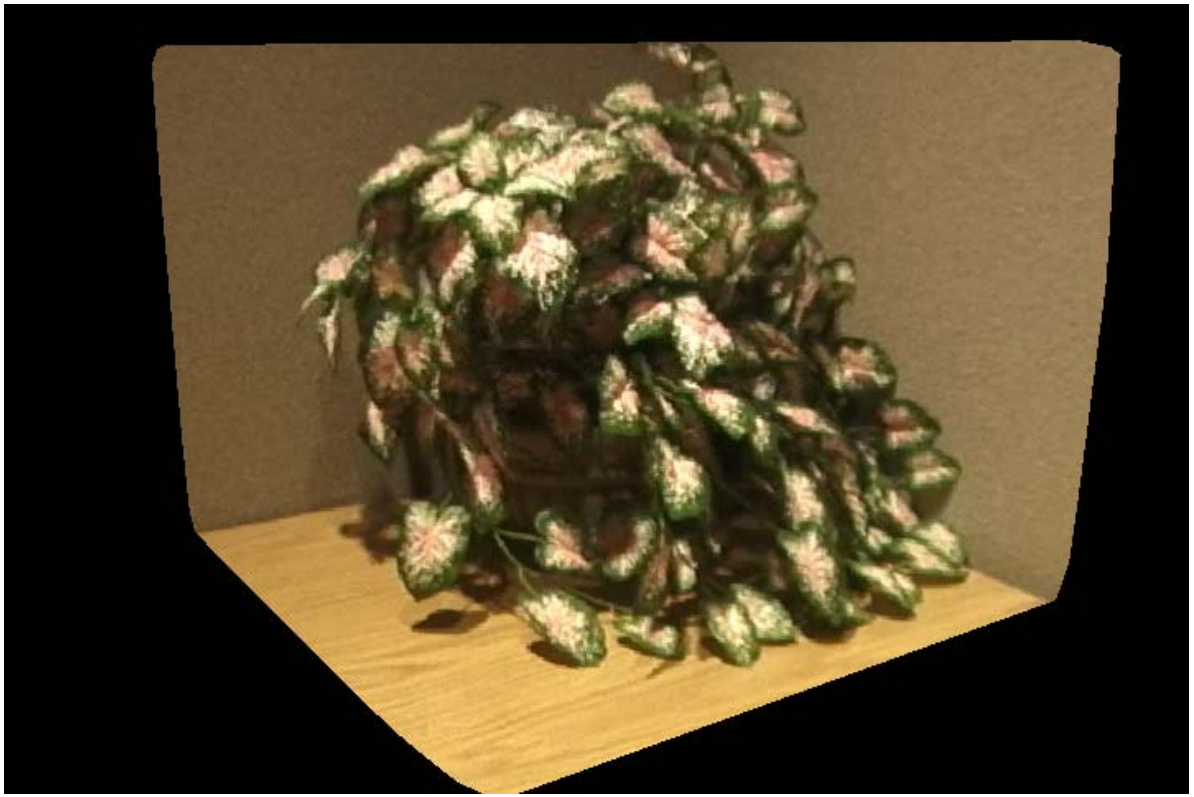
Compute 3D mesh

Rendering algorithm



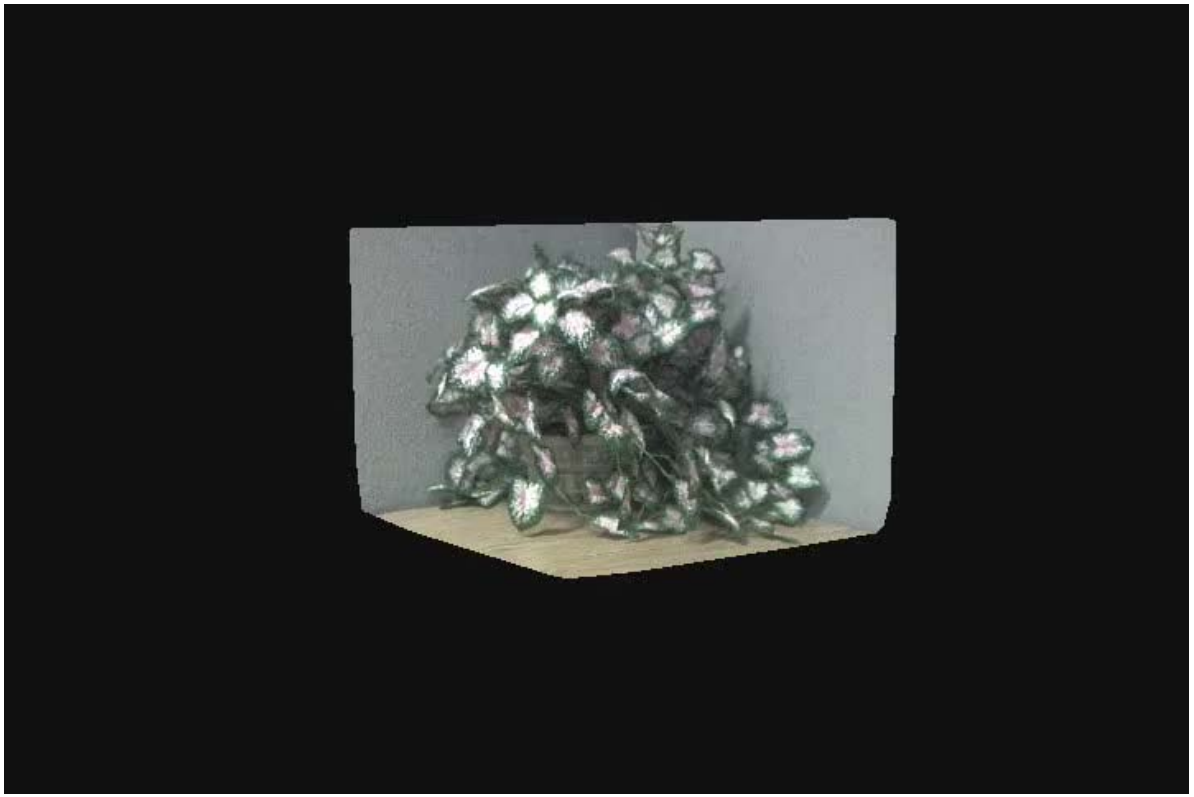
Color the 3D mesh

Rendering algorithm



Rendered image

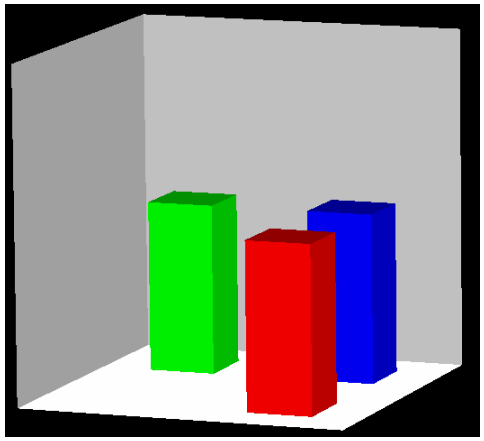
Rendering algorithm

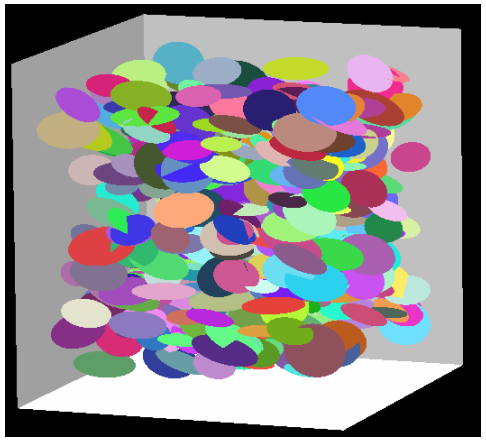


Rendering algorithm

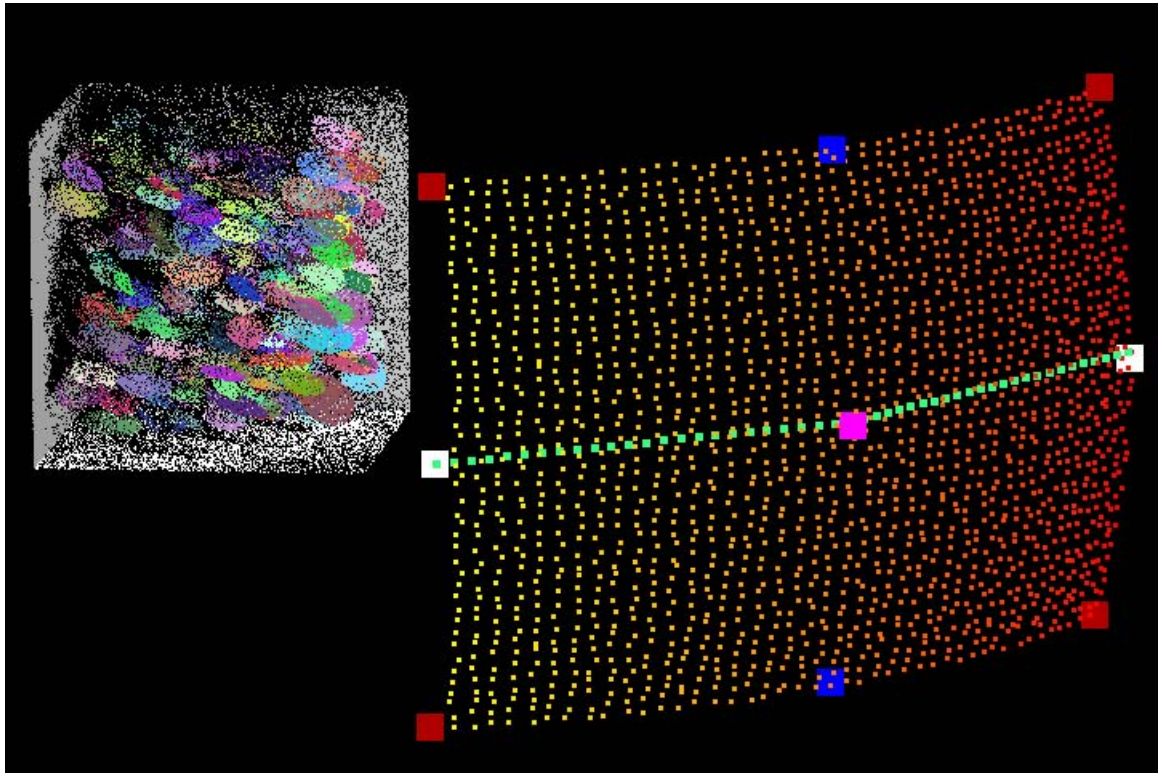
Scene coverage

- Comparison of SDDV to DDSV on simulated scenes
- Simulations run on 2 scenes





Simulations



Sampling locations used for scene analysis

5 DDSV simulations

- *1L pink large dot*
- *2LV blue*
- *2LH white*
- *4L red*
- *6L red+blue*

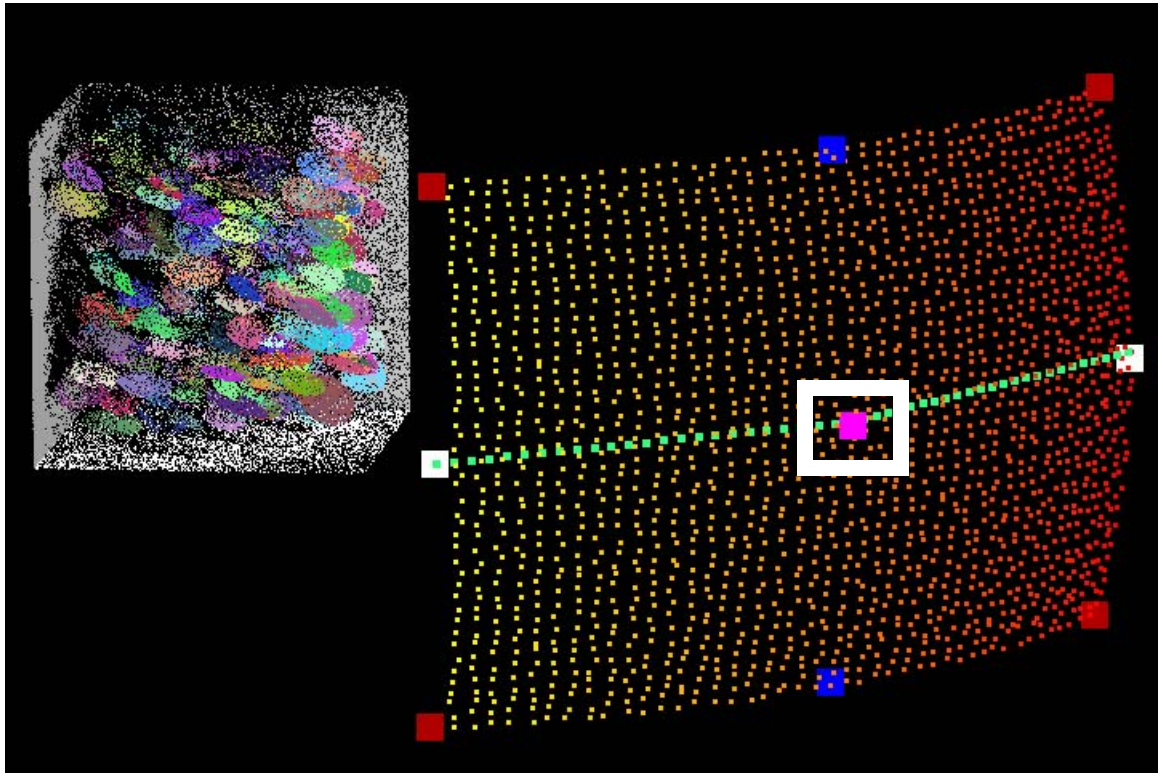
1 SDDV simulation

- *small yellow to red dots*

Rendering path

- *small green dots*

Simulations



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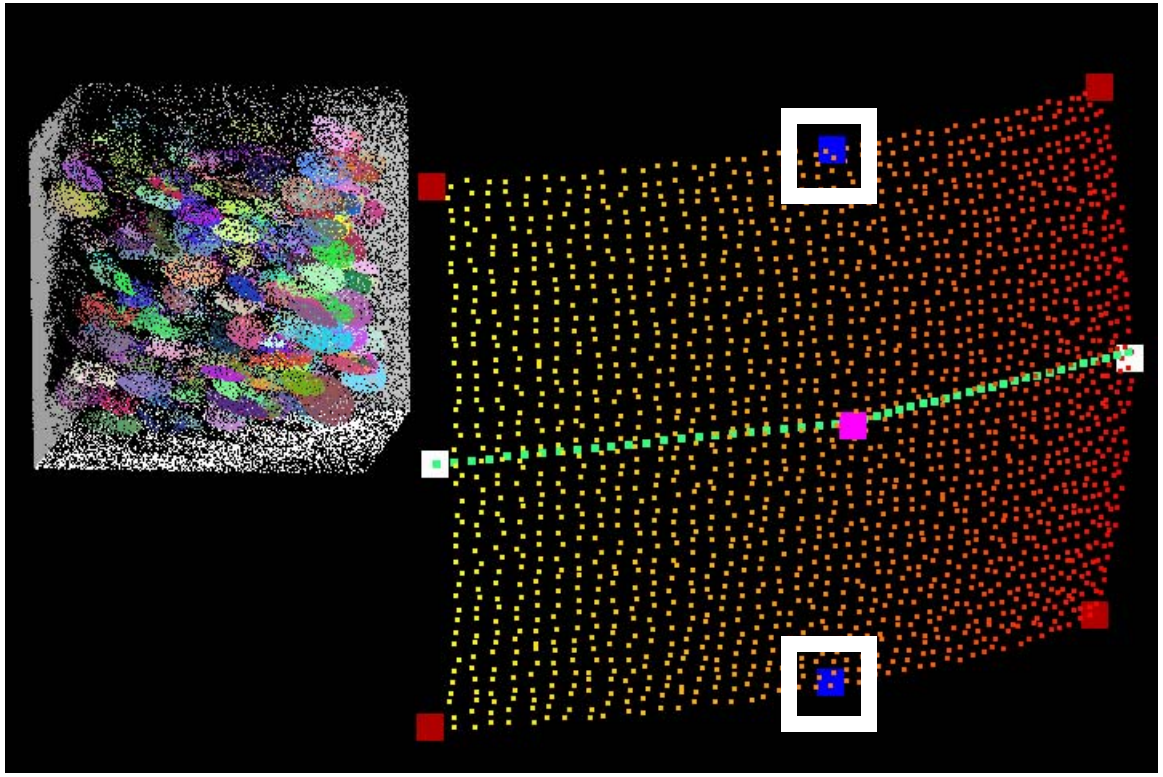

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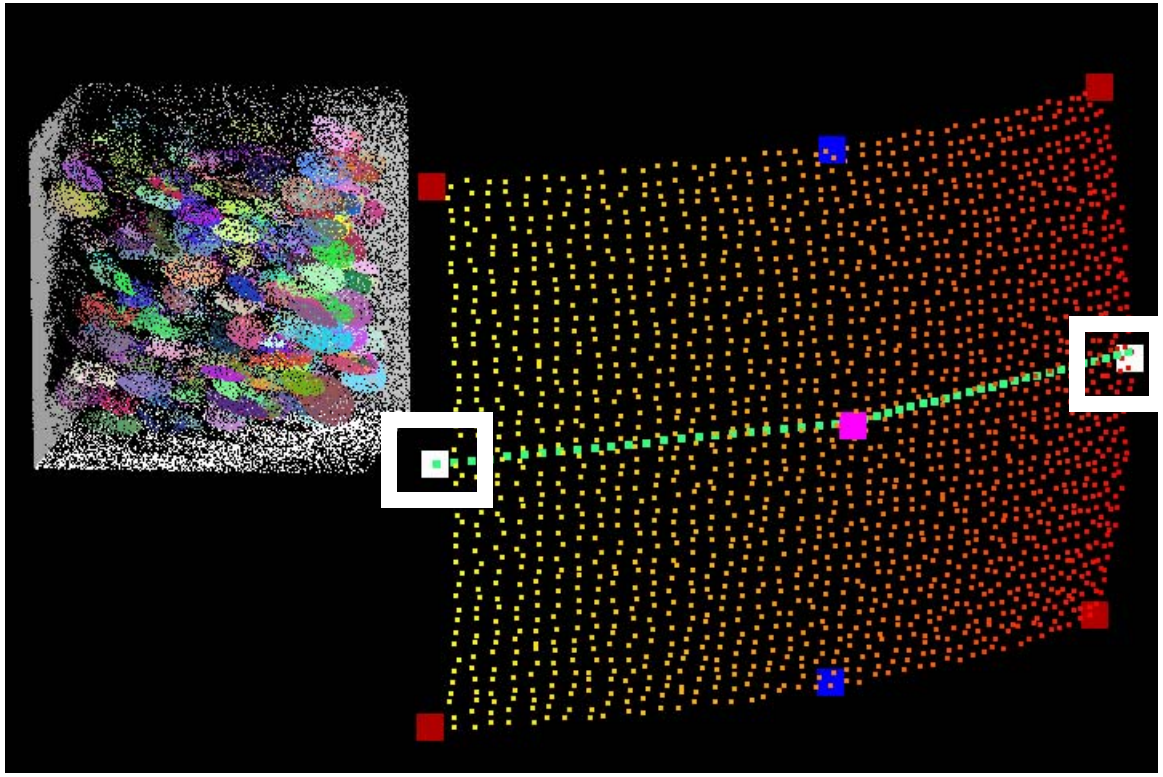

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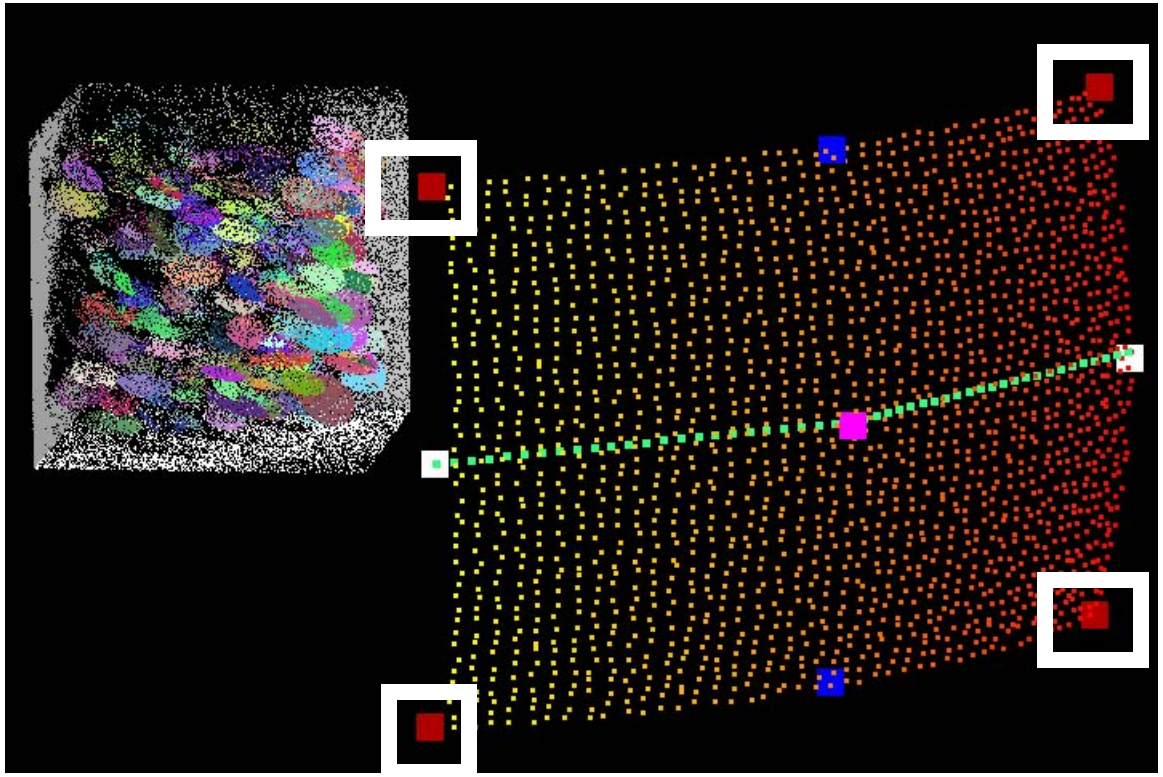

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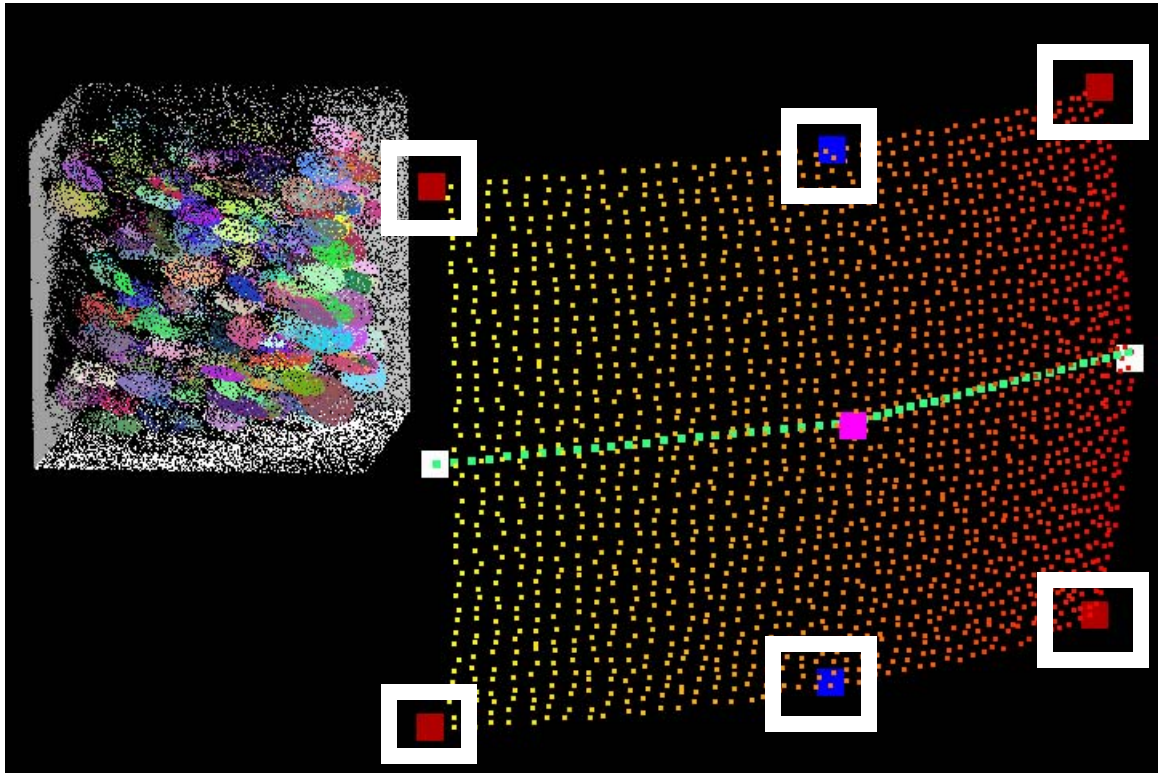

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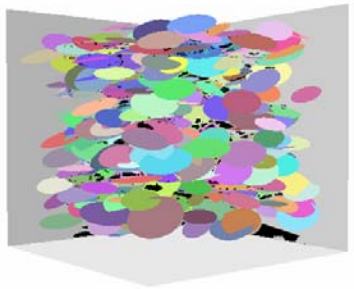
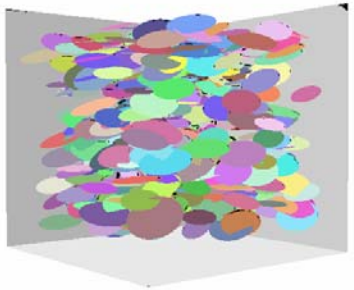
Scene coverage



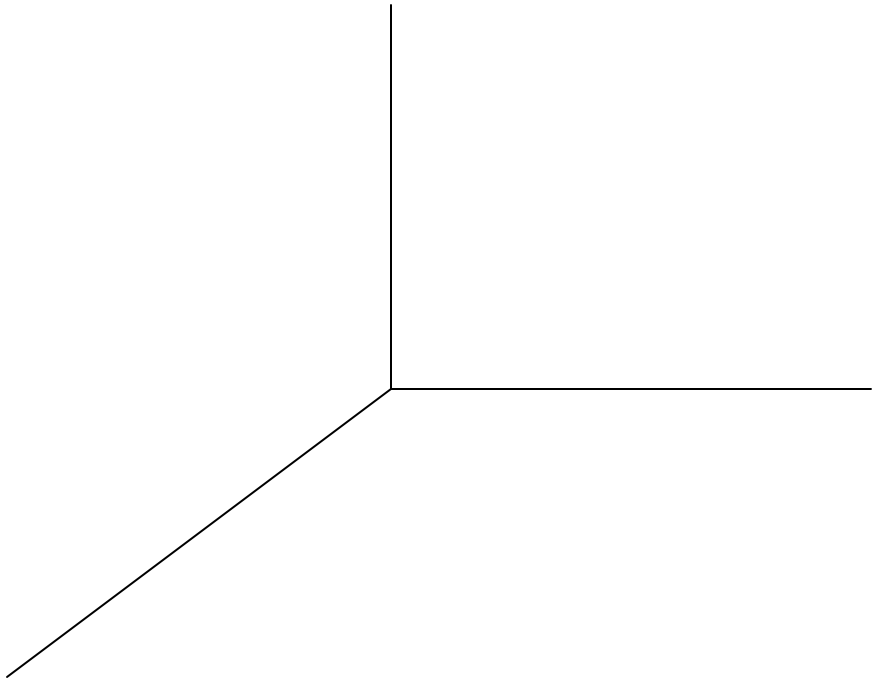
DDSV 6L



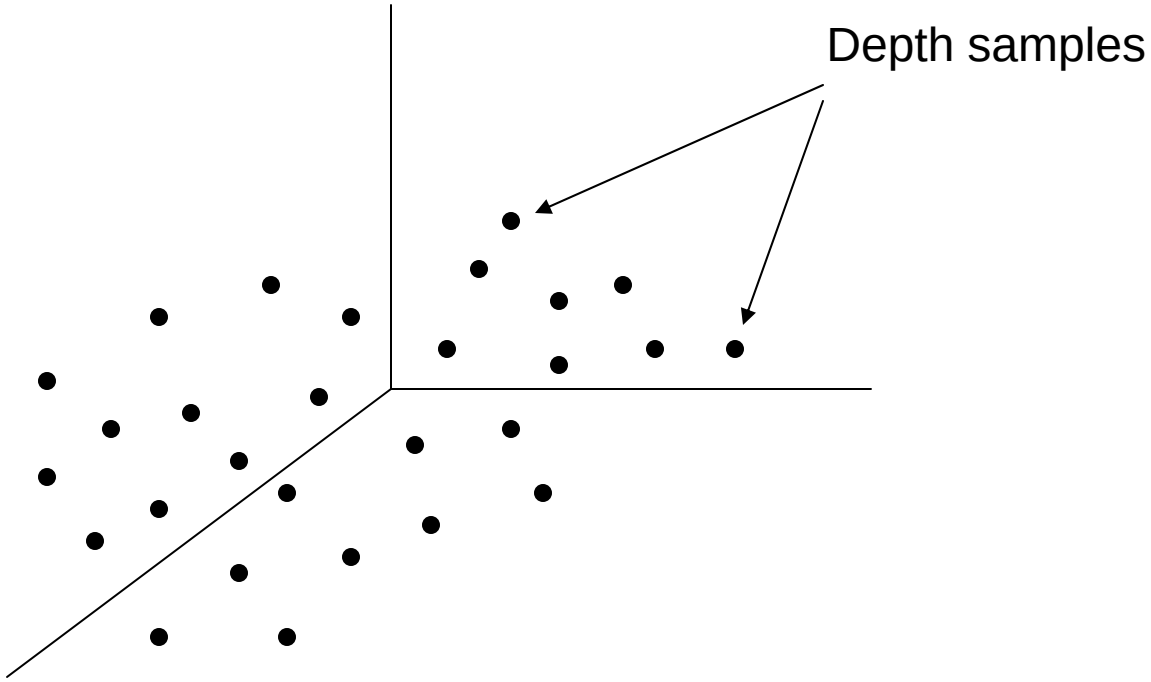
SDDV

- Indicated as fraction of missing samples for frames along rendering path
- A ground truth image sample is missing if
  - not present in any of the DDSV depth maps
  - not present in SDDV reconstruction
- Synthetic scenes are planar so missing samples detected robustly (no epsilons)

Ideal SDDV reconstruction



Ideal SDDV reconstruction



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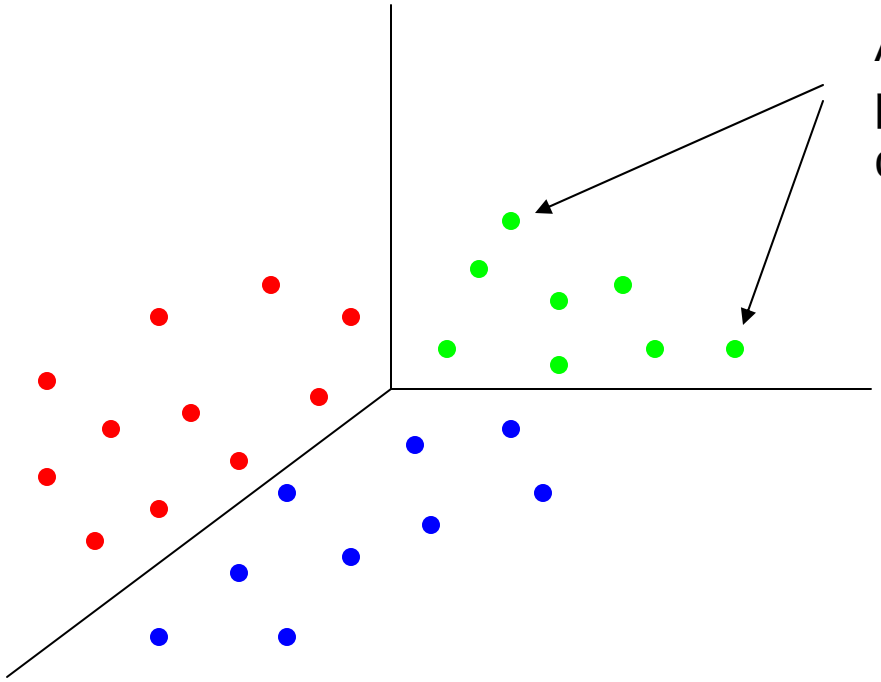
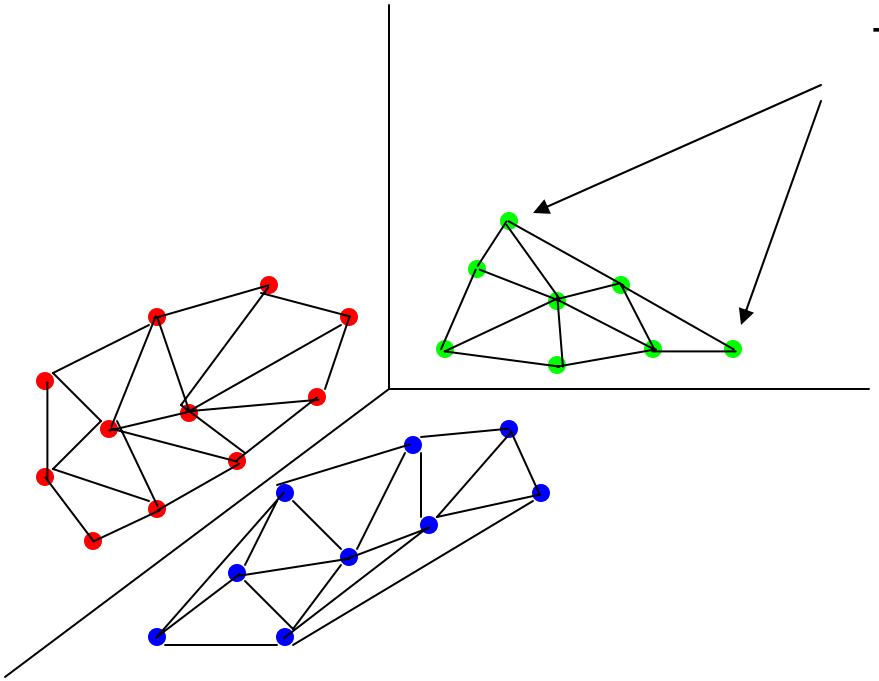


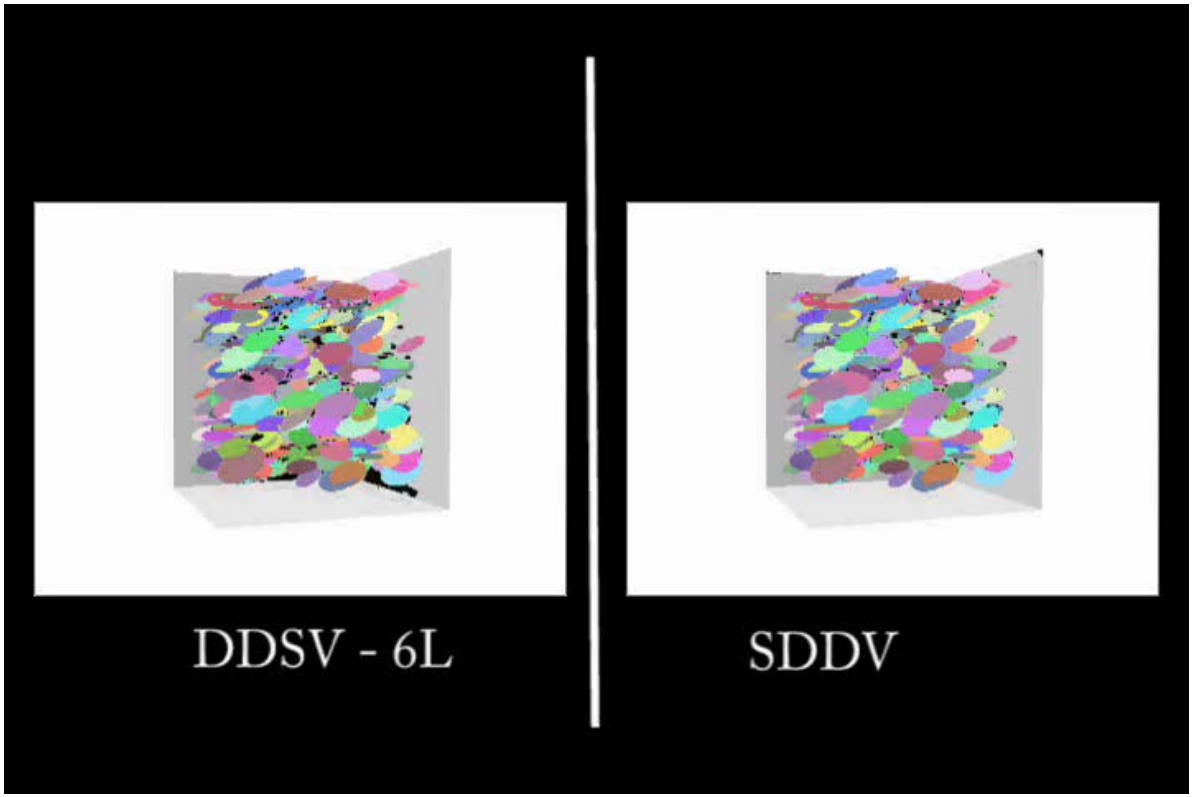
Assign samples to planes using their color

Ideal SDDV reconstruction



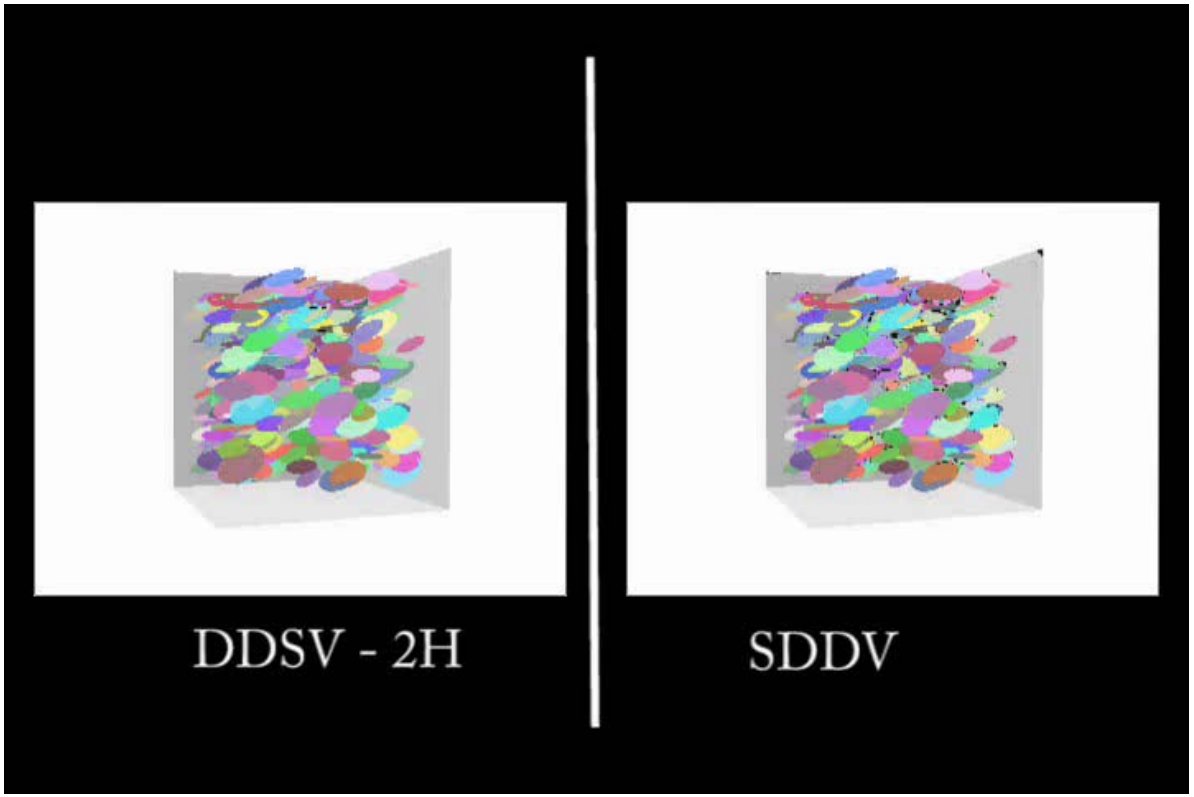
Triangulate in plane

Scene coverage results



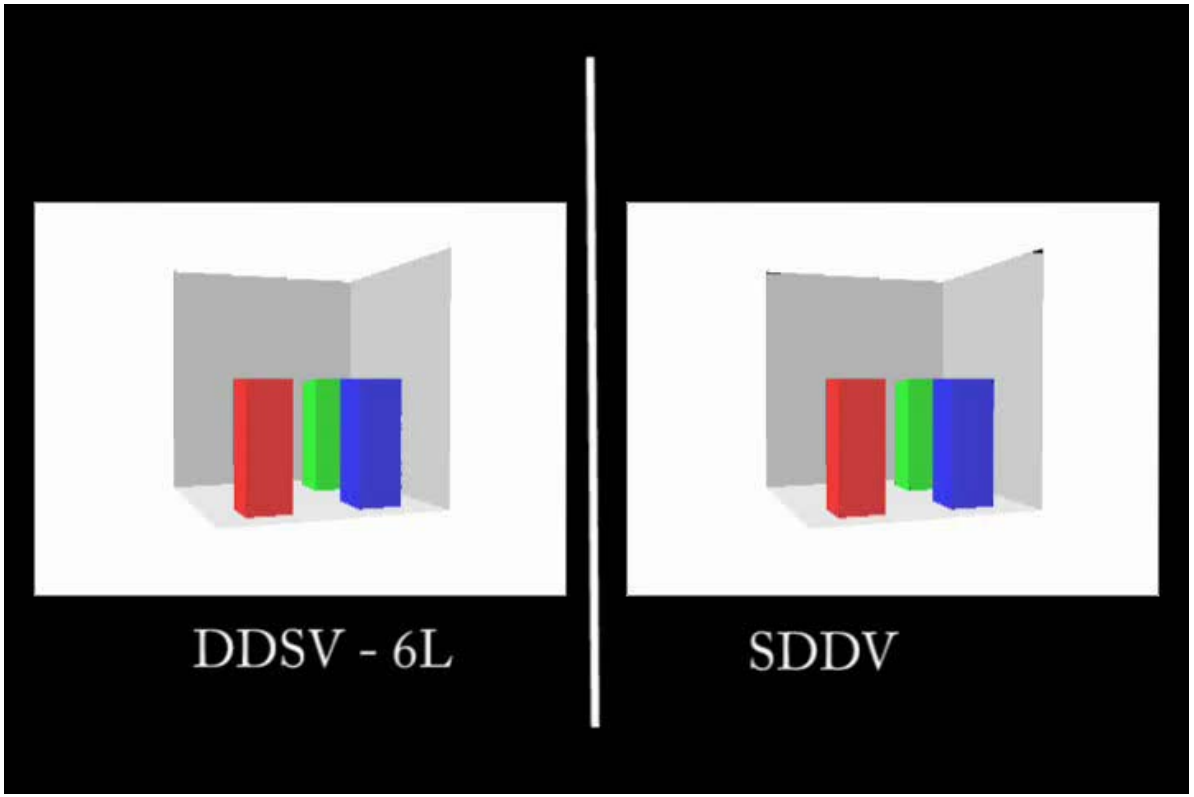
Comparison between SDDV and DDSV with 6 dense depth sampling locations

Scene coverage results



Comparison between SDDV and DDSV with 2 dense depth sampling locations (2H)

Scene coverage results



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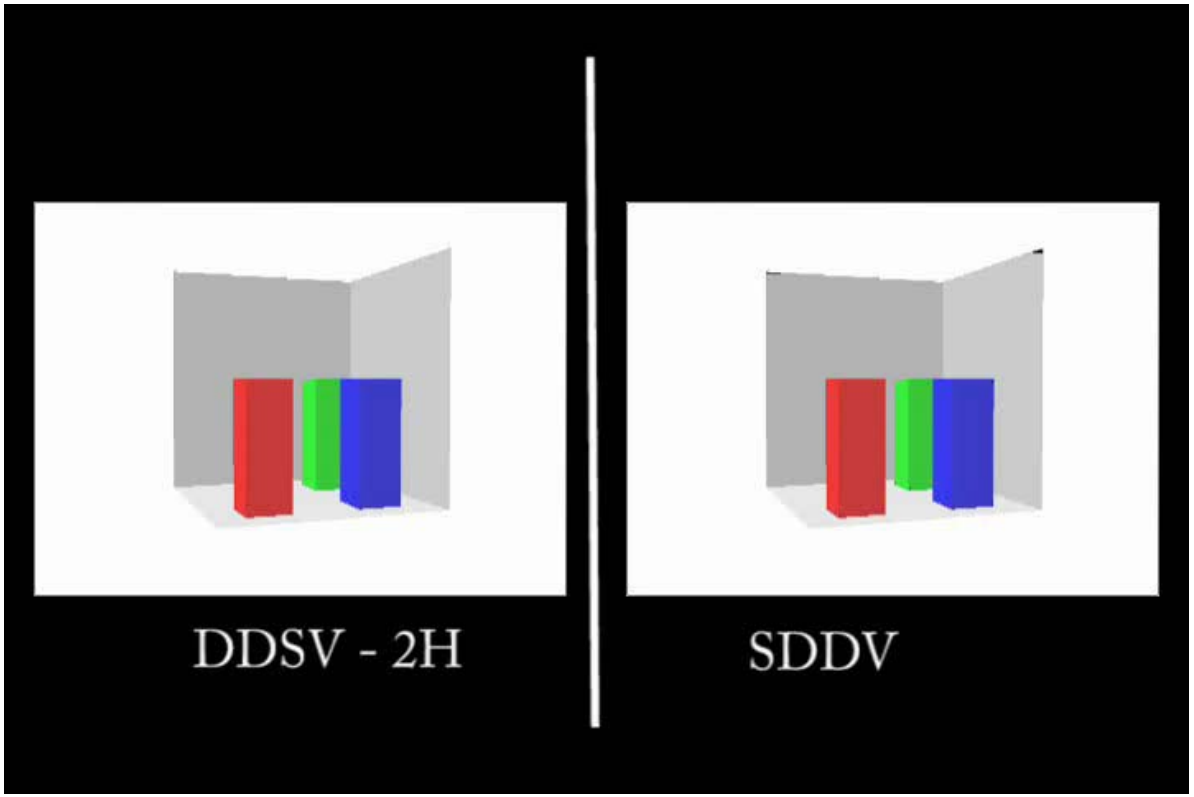


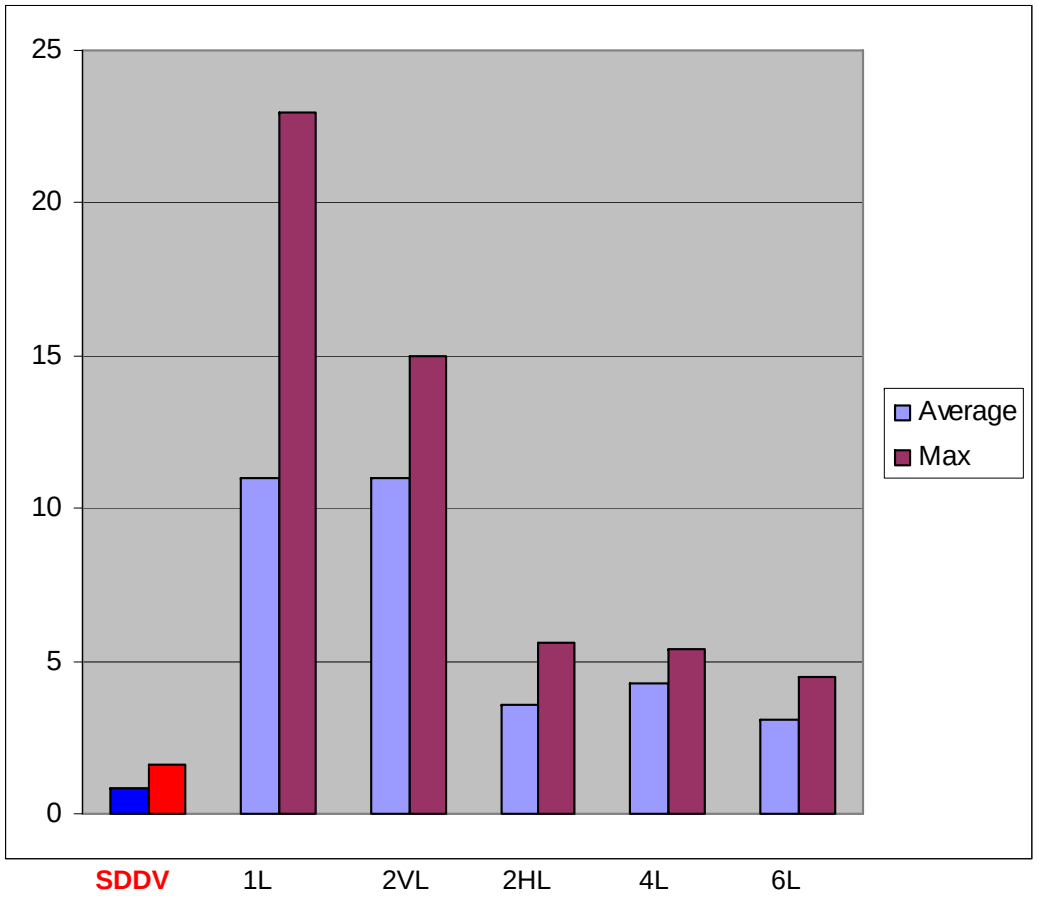
Comparison between SDDV and DDSV with 2 dense depth sampling locations (2H)

Scene coverage results

Scan time

SDDV : 10mins

DDSV : 30min/loc



Disks scene

Scene coverage results

Scan time

SDDV : 10mins

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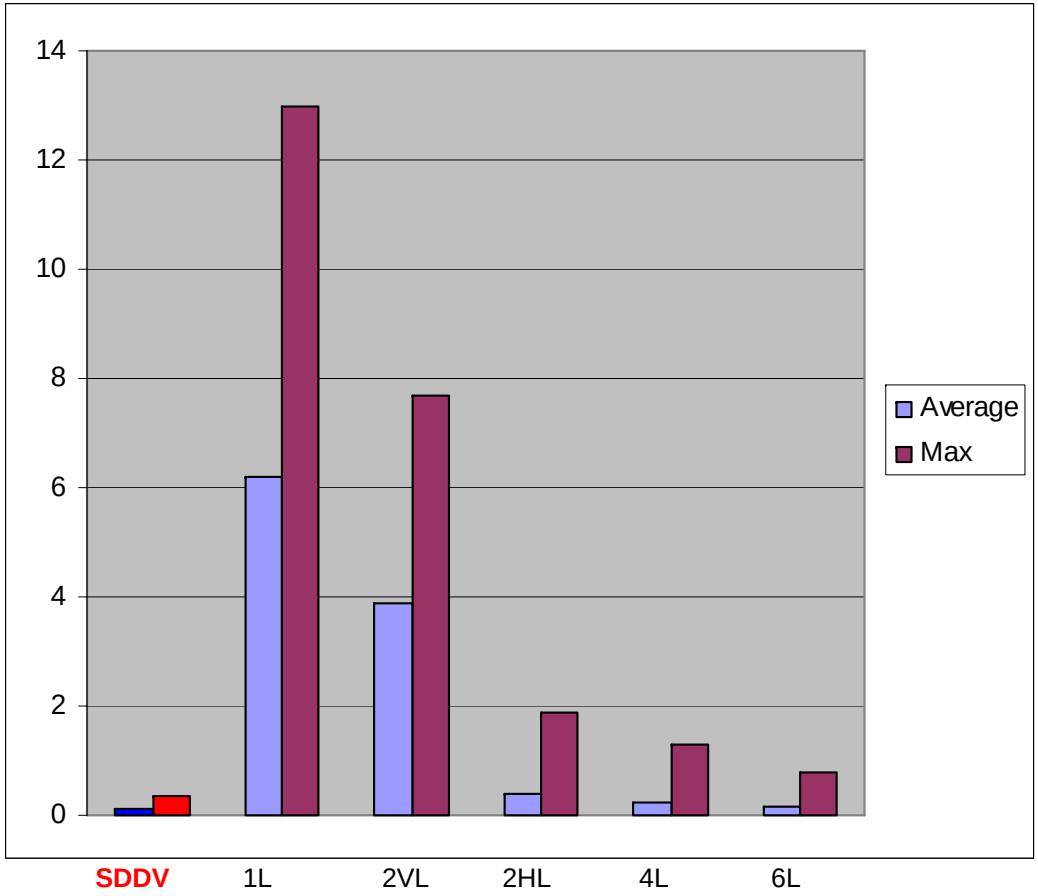
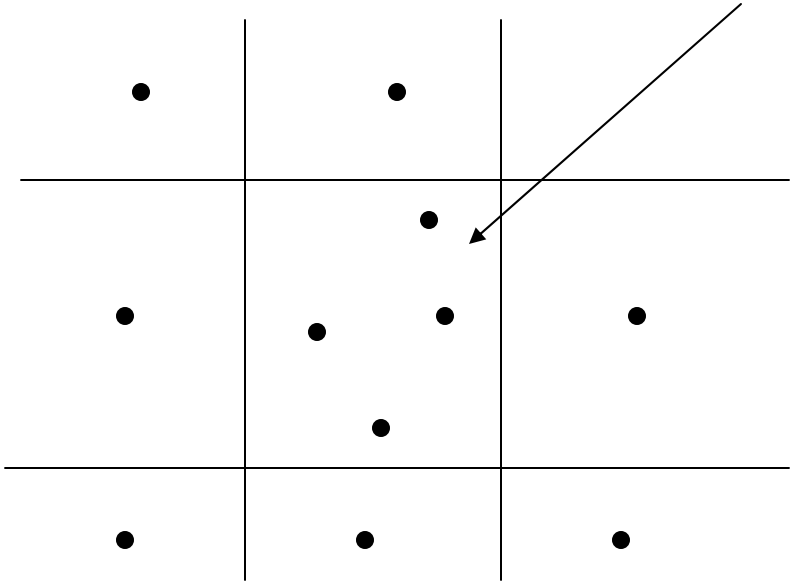


Boxes scene

Sampling redundancy

- Defined per rendering frame
- Average over pixels
- Redundancy at pixel
  - Number of visible samples that project to the pixel, minus 1

Sampling redundancy



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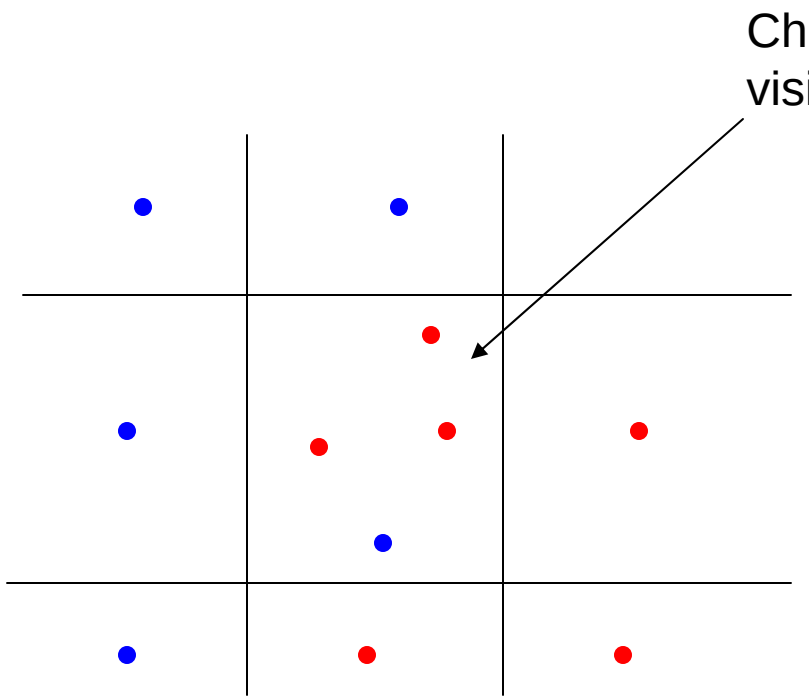
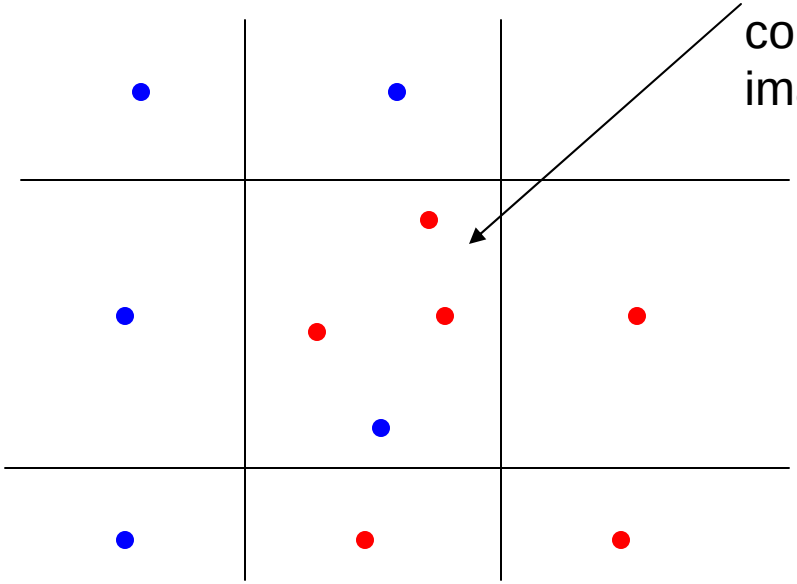
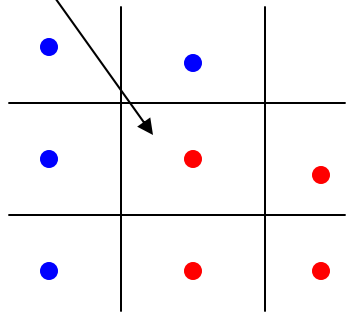


Sampling redundancy



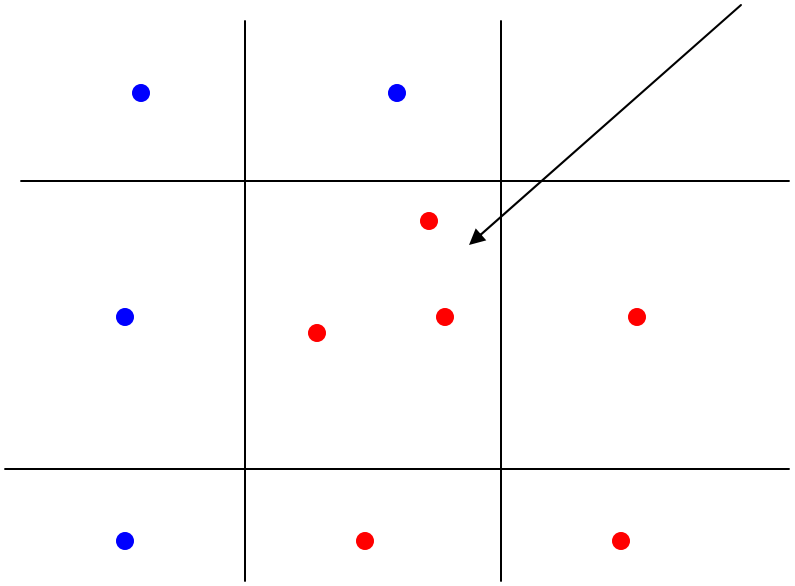
Check which samples are visible by comparing with the color in the ground truth image



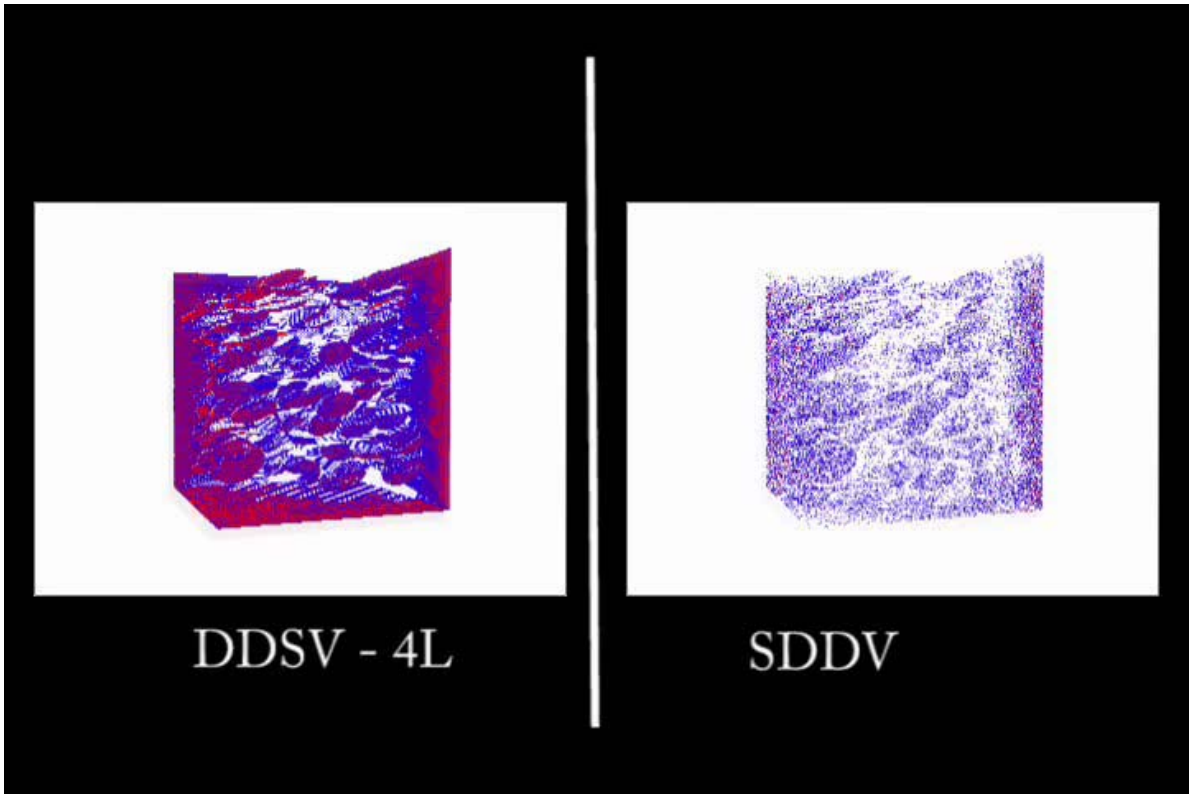
Ground truth image

Sampling redundancy

Pixel redundancy = 2



Redundancy results



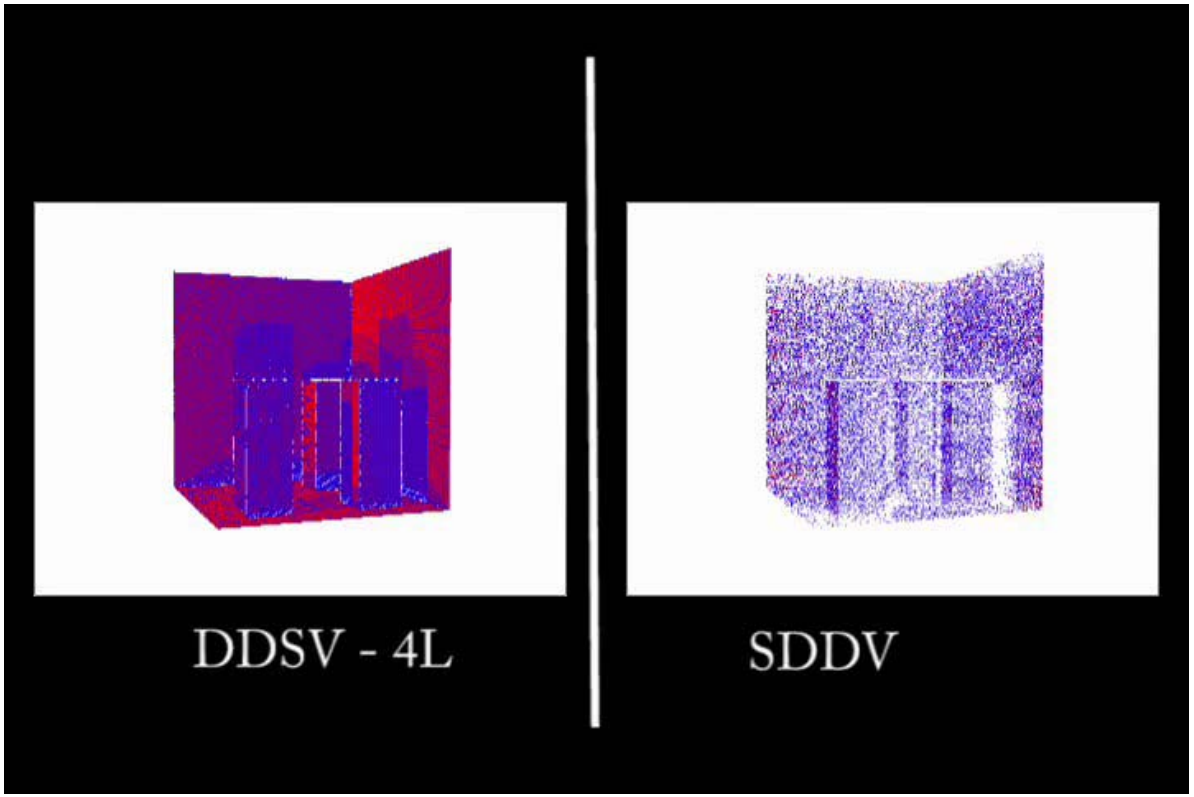
Redundancy

Blue : 1

Red : 4

Frame redundancy comparison between SDDV and 4L

Redundancy results



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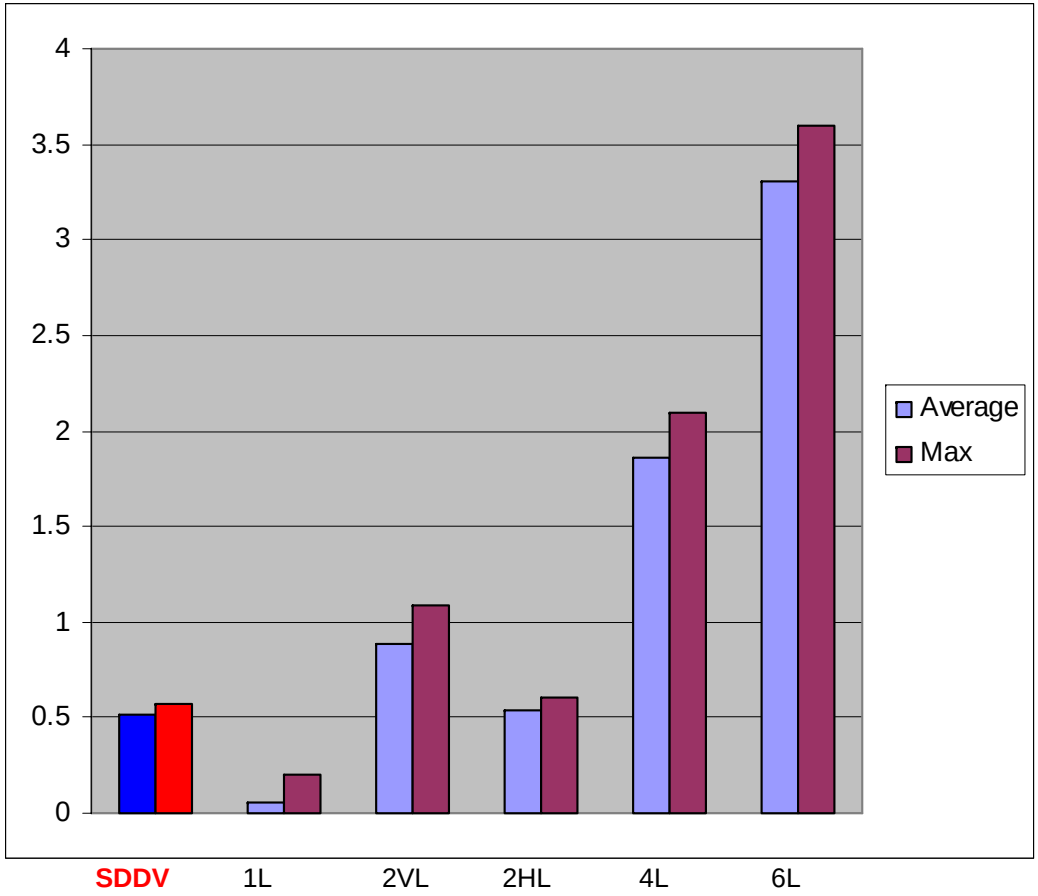

Disks scene

Redundancy results

Scan time

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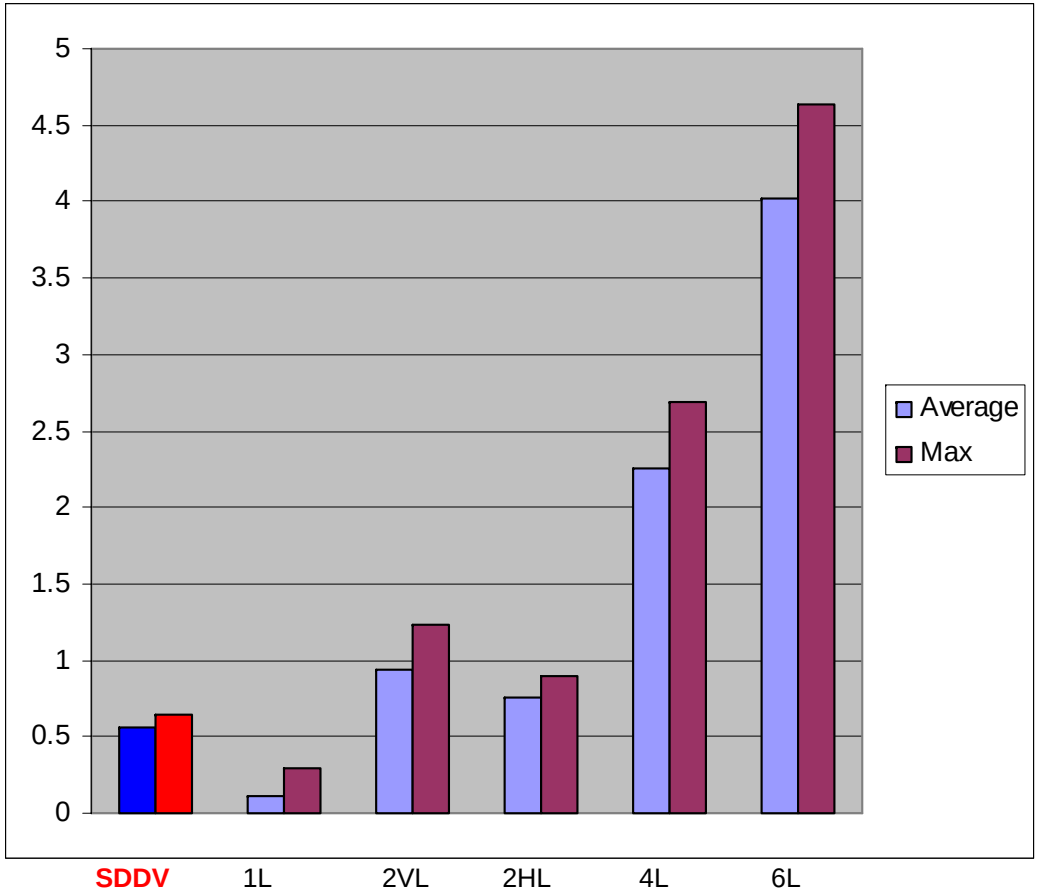
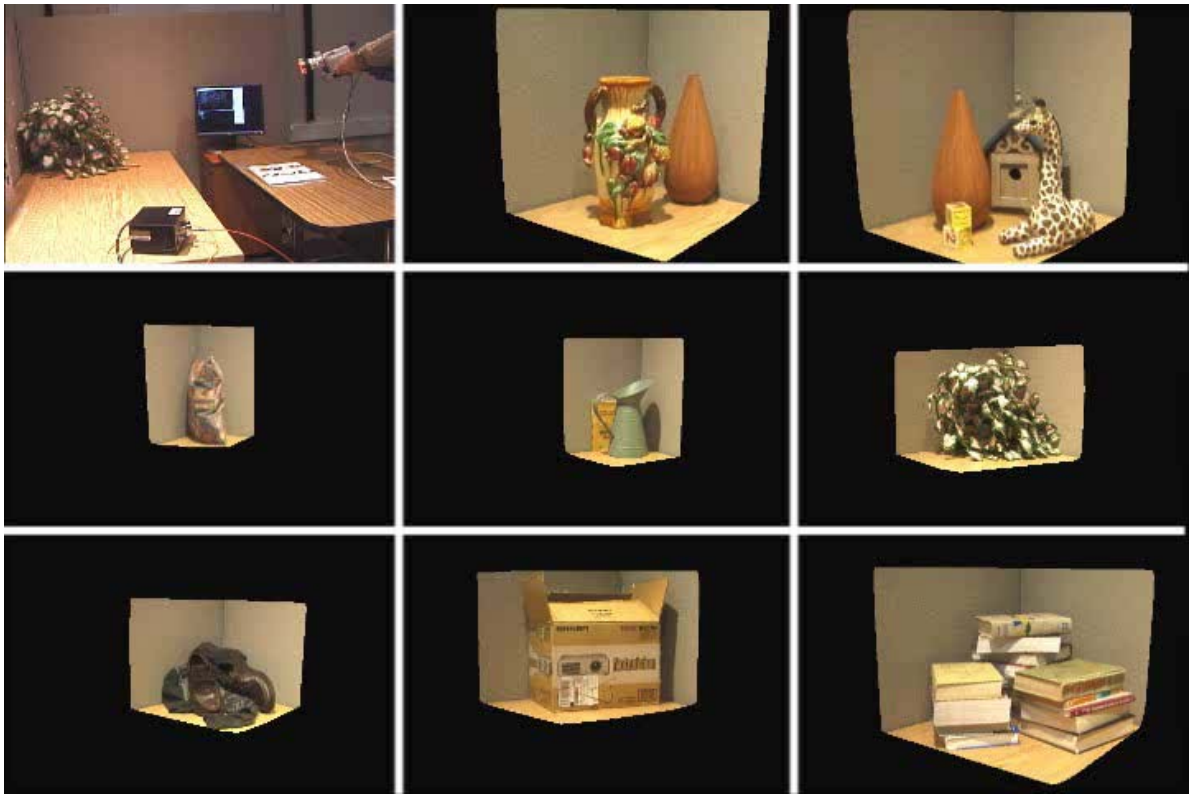


Boxes scene

Results

- SDDV tested on various models
  - Simple and complex geometry
  - Simple and complex surface properties

Results



Models acquired with our system

Comparison with Light Field

Light Field rendered using color data from our model - focused at the scene centroid

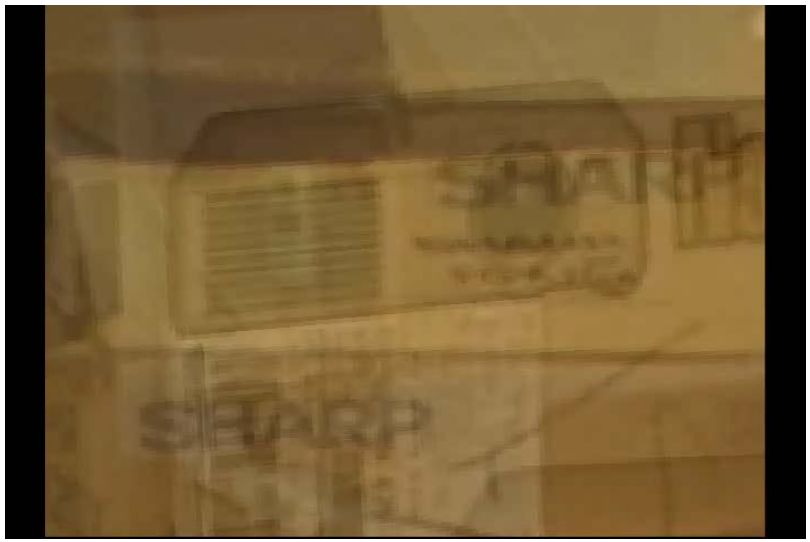
Image rendered from our model

Comparison with Light Field

Light Field rendered using color data from our model - focused at infinity

Image rendered from our model

Comparison with Light Field



Light Field rendered using color data from our model

Image rendered from our model

Limitations

- We cannot detect dots on highly specular surfaces
- We have difficulty detecting dots on the certain patterns
- Rendering bright scenes
- Occasional loss of precision in pose estimation from the arm

Conclusions

- SDDV
  - faster than DDSV
  - better scene coverage than DDSV
  - lower data redundancy than DDSV
- Our implementation of SDDV
  - Efficient automated modeling system
  - Handles various scenes robustly
  - High quality reconstruction at interactive rates
  - Scanning in place without altering lighting conditions

Future work

- Color balancing for frames
- Extend to inside-looking-out modeling
- Many features already in place
  - Sufficient depth range
  - Does not require altering the scene conditions

Thank you