VR'05 Tutorial:
Real-Time Collision Detection for Dynamic Virtual Environments

Image-Space Techniques

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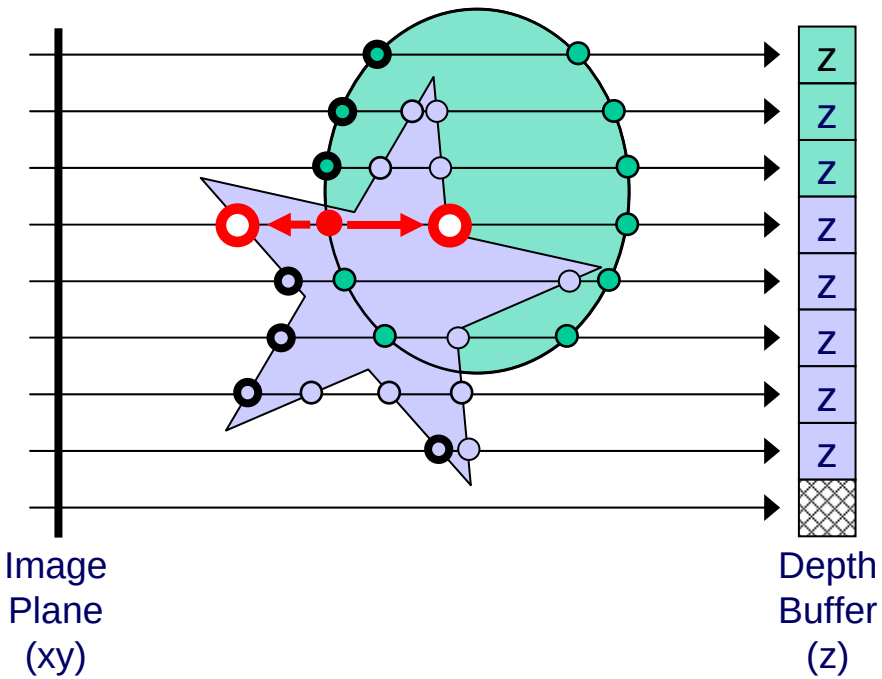
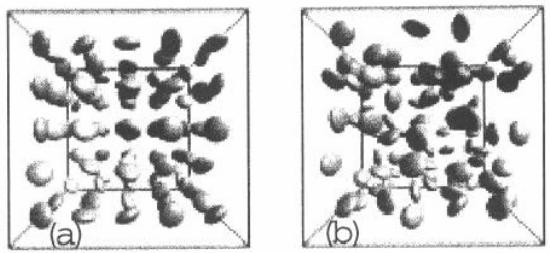
Basic idea

- Exploit rasterization of object primitives as intersection test
- Benefit from graphics hardware acceleration

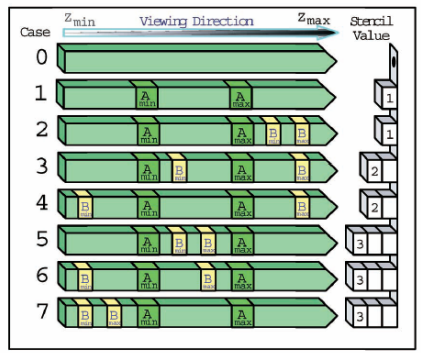


Early approaches

[Shinya, Forgue 1991]
Image-space collision detection for convex objects



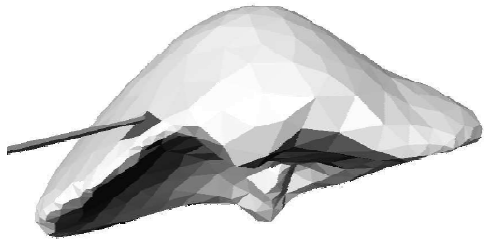
[Myszkowski, Okunev, Kunii 1995]
Collision detection for concave objects with limited depth complexity



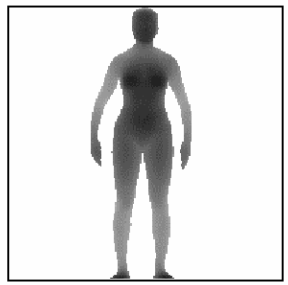
[Baciu, Wong 1997]
Hardware-assisted collision detection for convex objects

More approaches

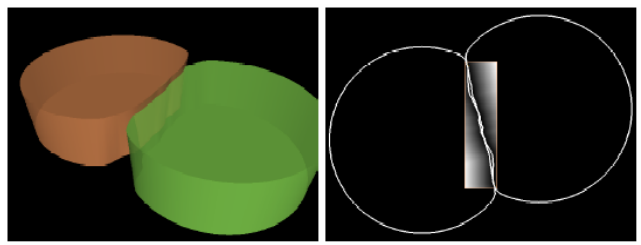
[Lombardo, Cani, Neyret 1999]
Intersection of tool with deformable tissue
by rendering the interior of the tool



[Vassilev, Spanlang, Chrysanthou 2001]
Image-space collision detection
applied to cloth simulation

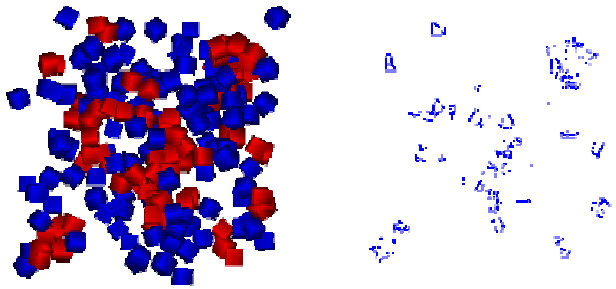


[Hoff, Zaferakis, Lin, Manocha 2001]
Proximity tests and later penetration
depth computation

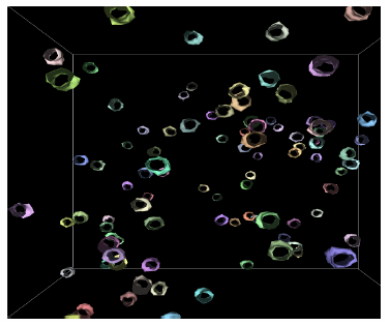


Recent approaches

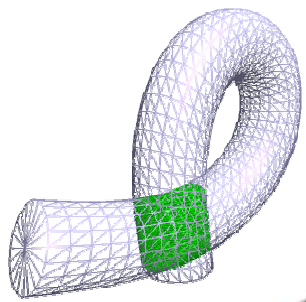
[Knott, Pai 2003]
Intersection of edges with surfaces



[Govindaraju, Redon, Lin, Manocha 2003]
Object and sub-object pruning based on occlusion queries

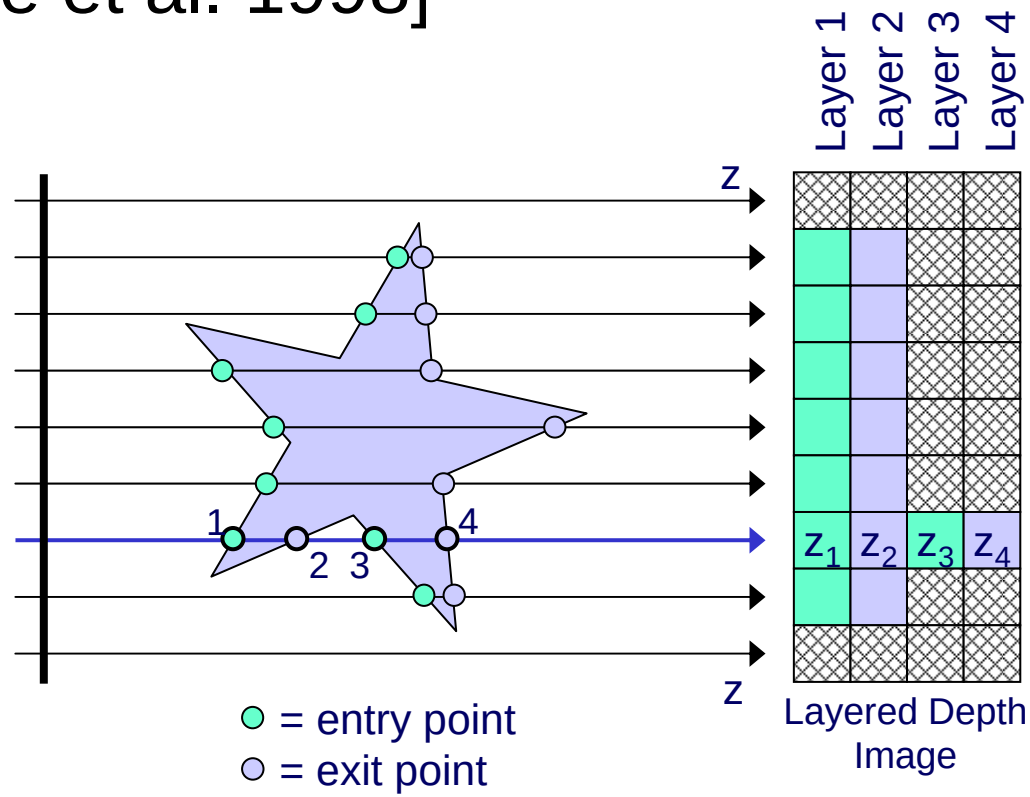


[Heidelberger, Teschner, Gross 2004]
Explicit intersection volume and self-collision detection based on LDIs



Layered depth images

- Compact, volumetric object representation [Shade et al. 1998]



Algorithm

Stage 1

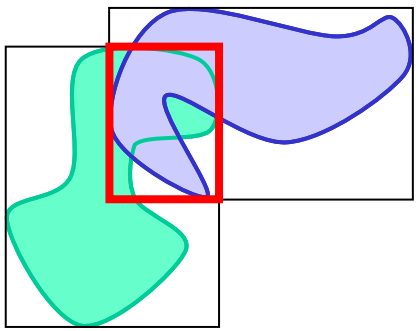
Volume-of-interest

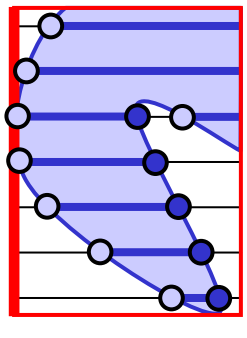
Stage 2

LDI generation

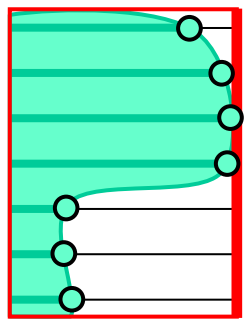
Stage 3

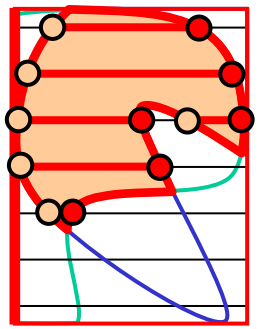
Collision query



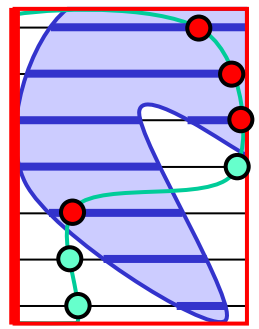


viewing direction

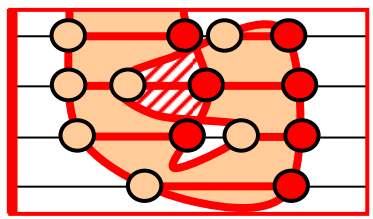




a) LDI intersection



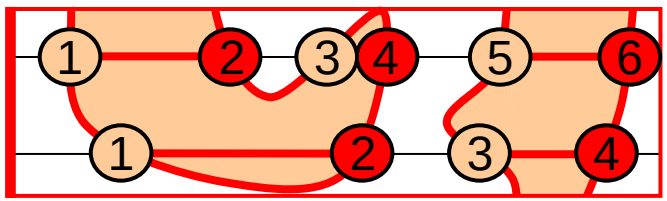
b) Vertex-in-volume



c) Self-collision

LDI generation

- Object is rendered once for each LDI layer
- Two separate depth test per fragment are required:
  - Fragment has to be farther than the one in the previous layer
  - Fragment has to be the nearest of all remaining fragments



Vol

1	2	3	4	5	6
1	2	3	4	4	4

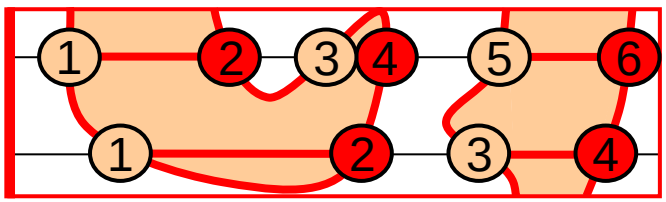
Ordered LDI

→ Shadow mapping functionality is a second depth test [Everitt 2001]

… or multiple depth textures and fragment shaders

Unordered LDI

- Fragments $z_1, \ldots, z_n$ are rendered in the same order in each rendering pass
- Employ the stencil buffer to generate the *n*-th value in the *n*-th pass



VoI

5	3	2	1	4	6
4	1	3	2	2	2

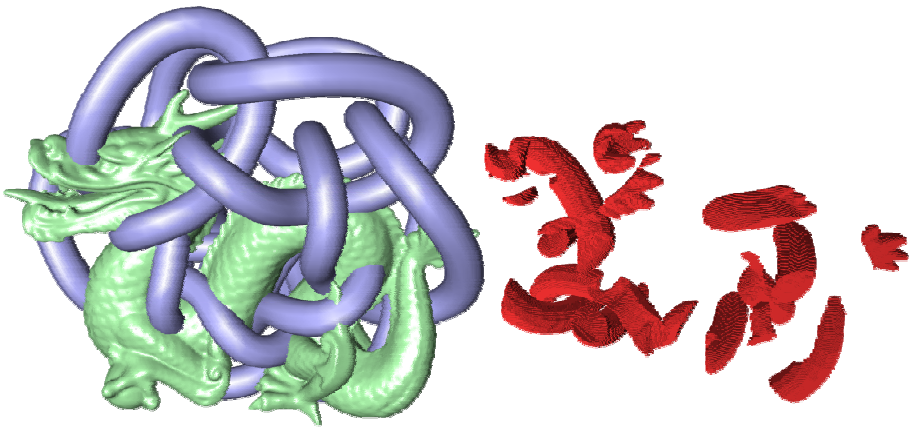
Unordered LDI

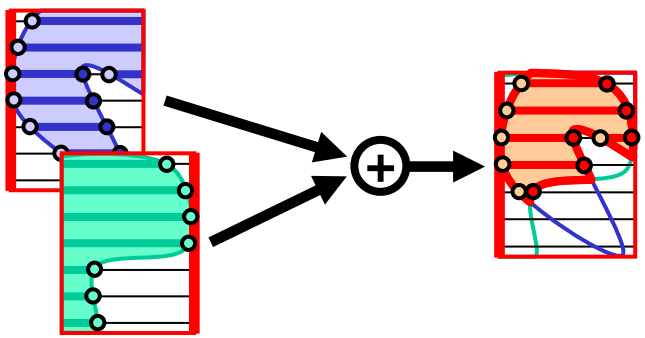
→ No depth test required, just stencil tests

→ ~3x faster than ordered LDI approach!

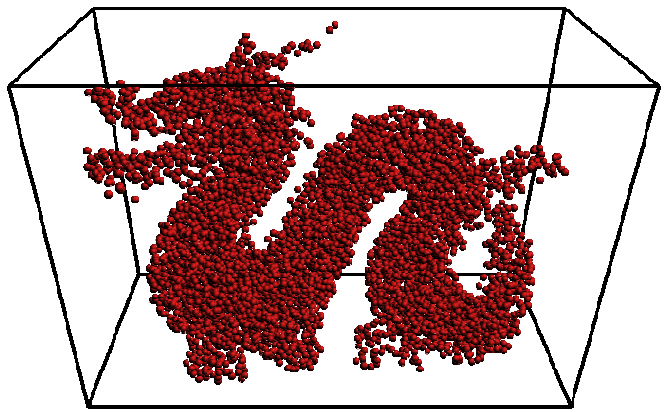
Collision queries

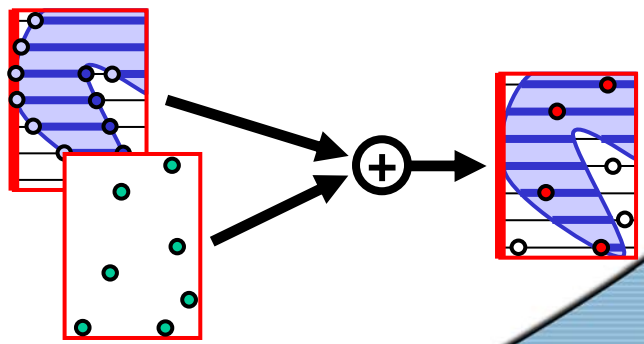
Explicit intersection volume





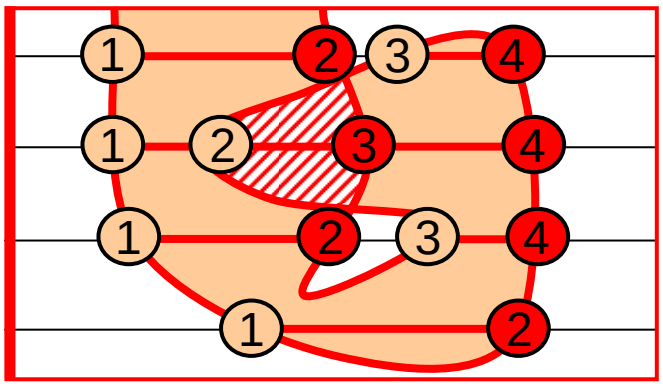
Vertex-in-volume test





Self-collision query

- Check for incorrect ordering of front and back faces



Vol

1	2	3	4
1	2	3	4
1	2	3	4
1	2	2	2

LDI

→ Requires two passes (front- then back-faces) and sorting of depth values

Ongoing work

- Precision
  - Image resolution, depth precision and render direction introduce errors
- Collision information
  - Penetration depth and direction required for appropriate collision response
- GPU
  - Bottleneck: framebuffer readback
  - Integration with collision response, simulation, rendering etc.

Conclusion

- Image-space techniques exploit the rasterization of objects for collision and self-collision detection
- No pre-processing required
- Suitable for rigid and deformable objects
- Related image-based methods exist for collision culling, proximity tests and penetration depth computation

The End

Thank you!