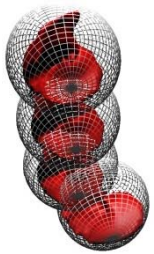

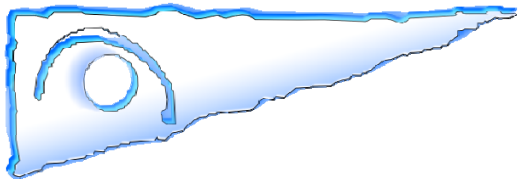

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Efficient Collision Detection and Physics-based Deformation for Haptic Simulation with Local Spherical Hash

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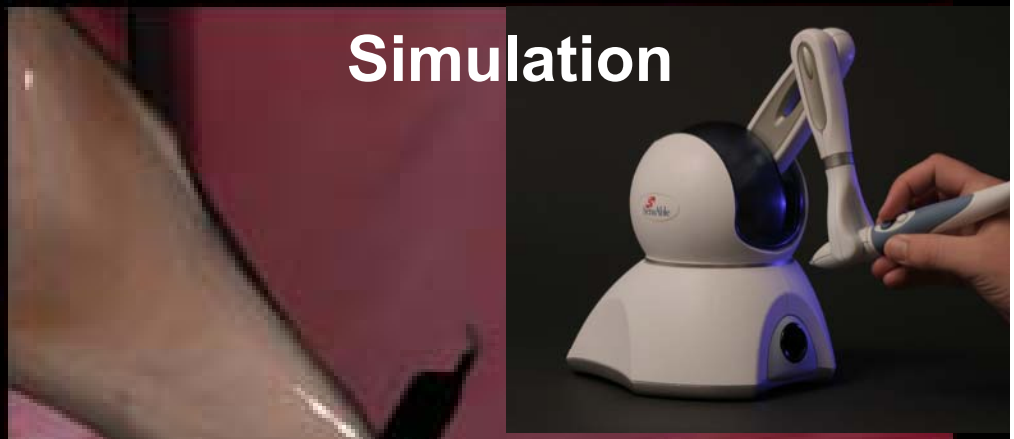
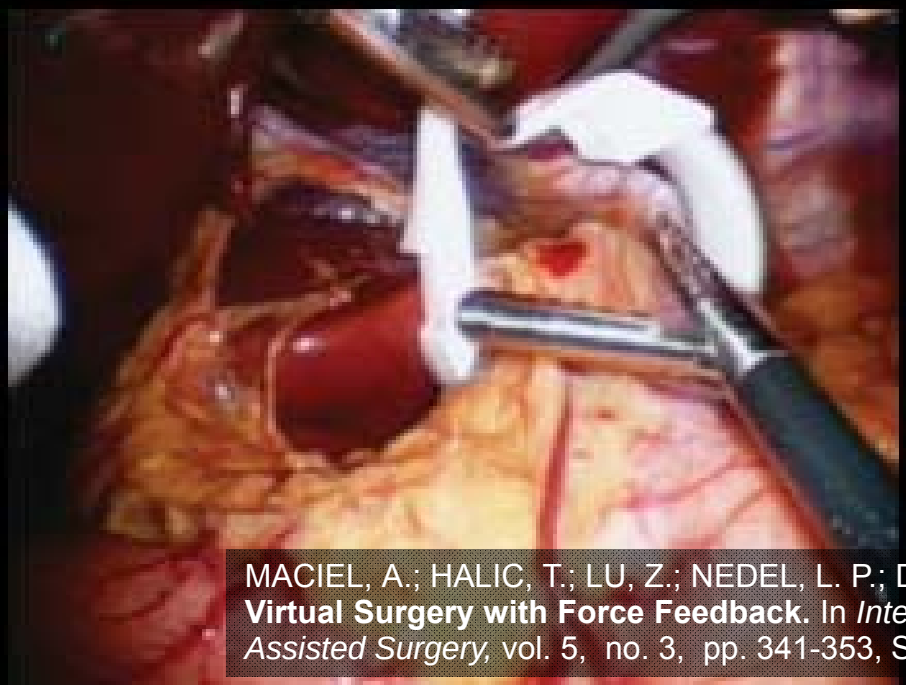
Motivation

Surgical Simulation





MACIEL, A.; HALIC, T.; LU, Z.; NEDEL, L. P.; DE, S. **Using the PhysX engine for Physics-based Virtual Surgery with Force Feedback.** In *International Journal of Medical Robotics and Computer Assisted Surgery,* vol. 5, no. 3, pp. 341-353, September, 2009. John Wiley & Sons, Ltd

Motivation

- Physics-based Simulation
  of Soft bodies = Deformation

- FAST Collision Detection
  with Local Spherical Hash

- For Haptic Interaction
  = high frame rate!

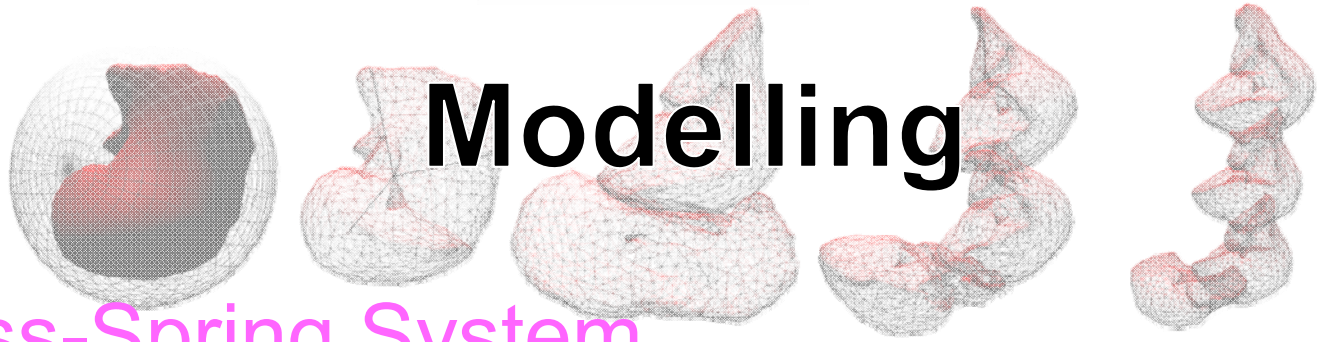
feedback device->

Organization

- Related Work
- Modeling the problem
- CPU and GPU Implementations
- Building the Local Spherical Hash
- The collision detection algorithm
- Haptics interface
- Results
- Conclusions

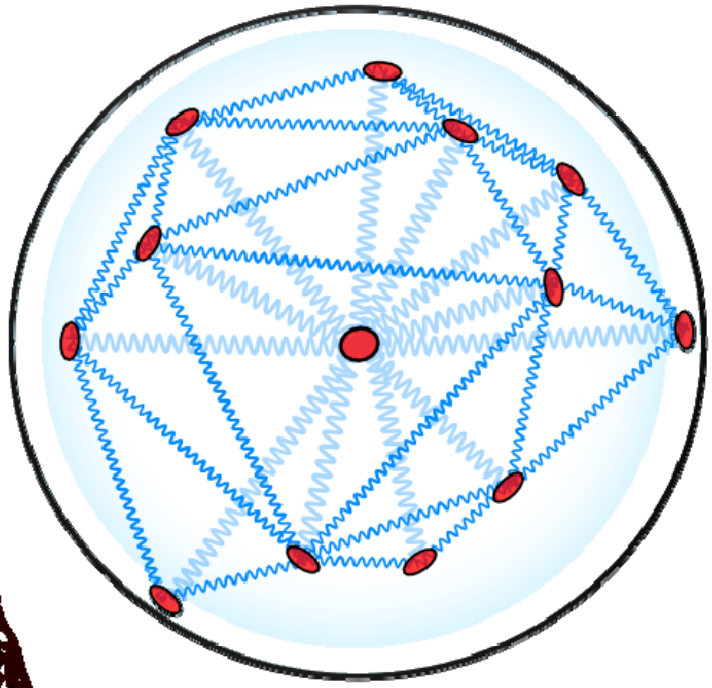
Related Work

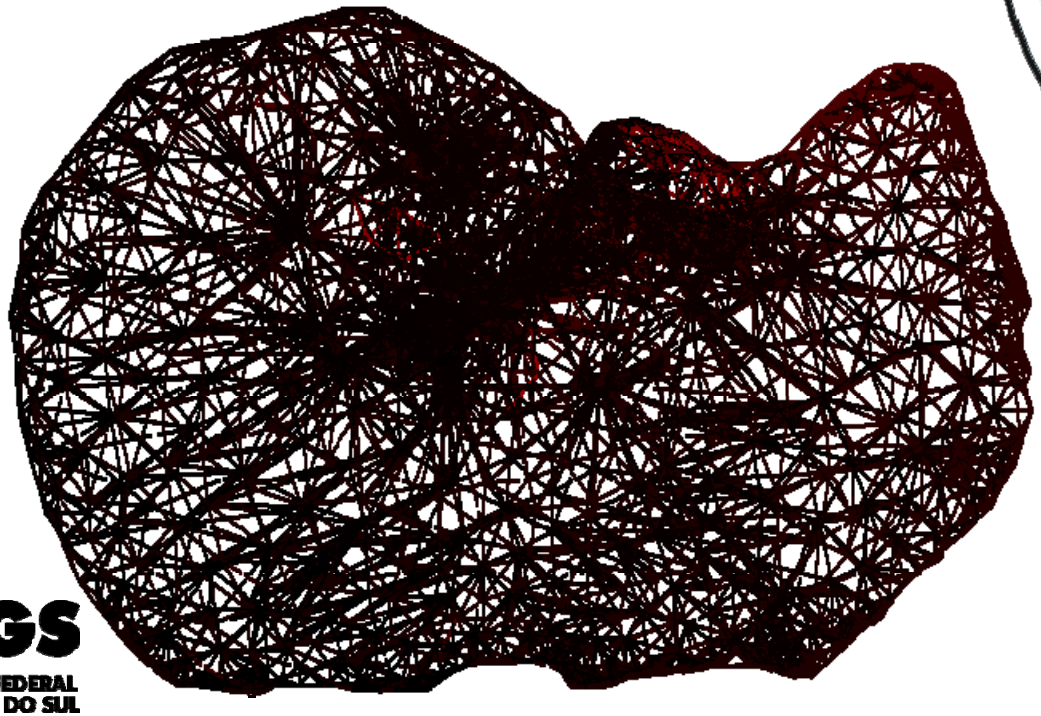
- OBB-trees [12,13]
  - Too slow for deformation
- Image based methods [14,15,16]
  - Limited information for collision response
- Spherical Sliding
  - Good for constant contact but does not alow large deformation
  - Problem: fixed local axes allow little deformation only



Modelling

- Mass-Spring System
- Tetrahedral mesh
- Vertex = Mass
- Edge = Spring





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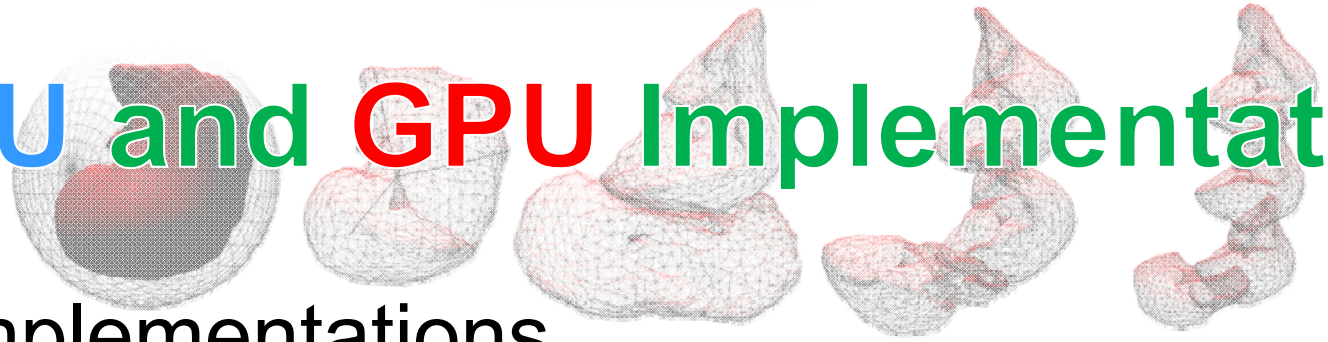


CPU and GPU Implementations

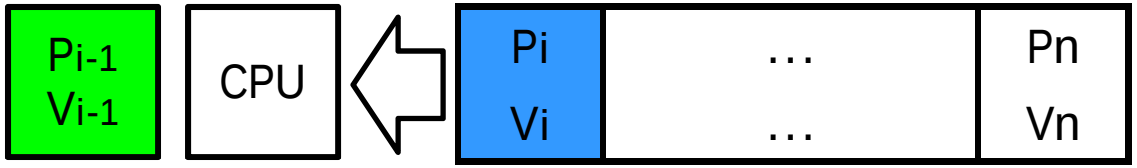
- 2 implementations
  - CPU x GPU
- Mass-spring system is highly parallelizable
  - large degree of independence between the particles
- Best memory organization?

CPU Memory Organization

- CPU fully evaluates one particle at time

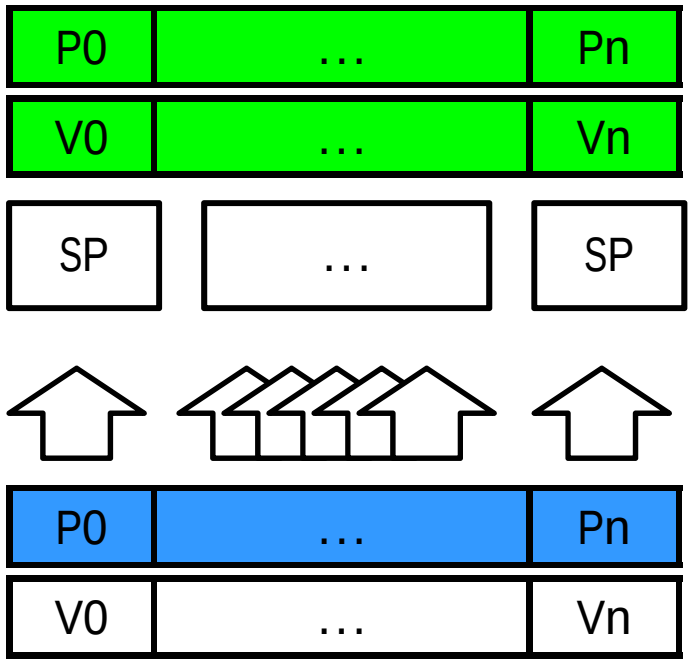
- The best cache locality
  keeps together the information
  for each particle

- Data organized in an array of structures



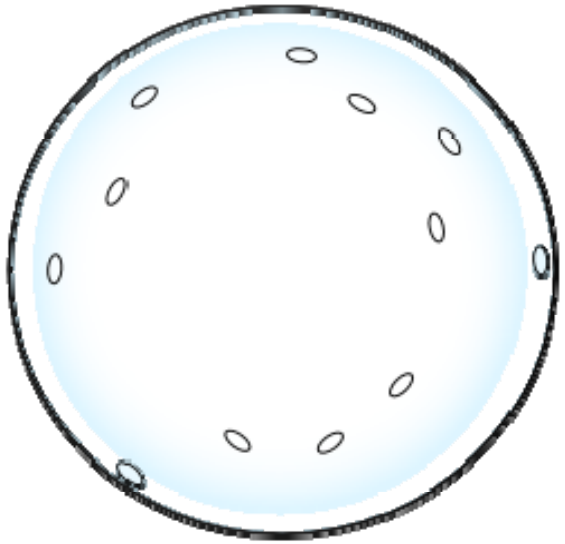
GPU Memory Organization

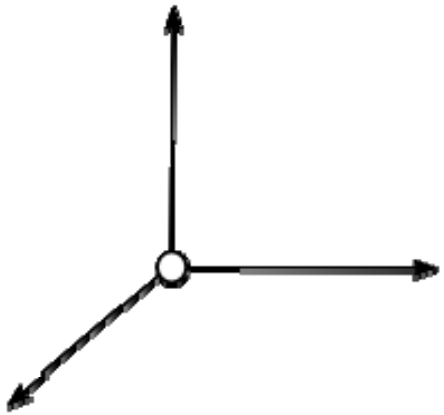
- GPU evaluates many particles in parallel
- The best cache locality keeps together the information **for each thread**
- Data organized in a structure of arrays



Building The Hash

Preprocessing step

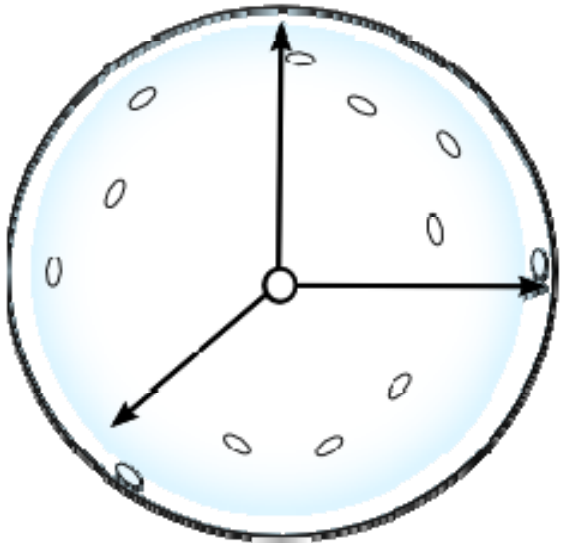




Building The Hash

Preprocessing step

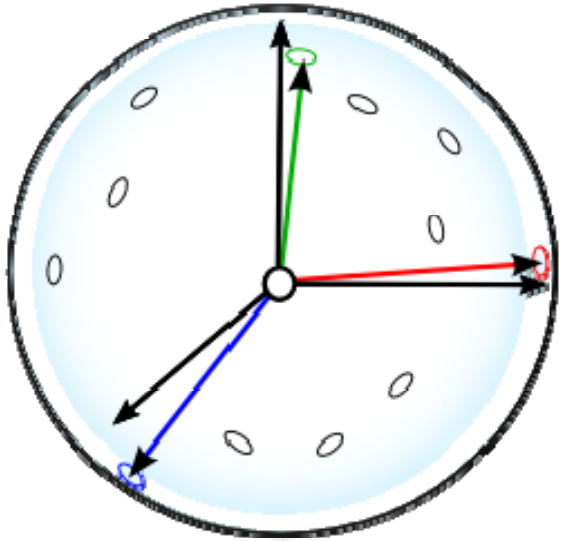
- Translate the mesh to origin



Building The Hash

Preprocessing step

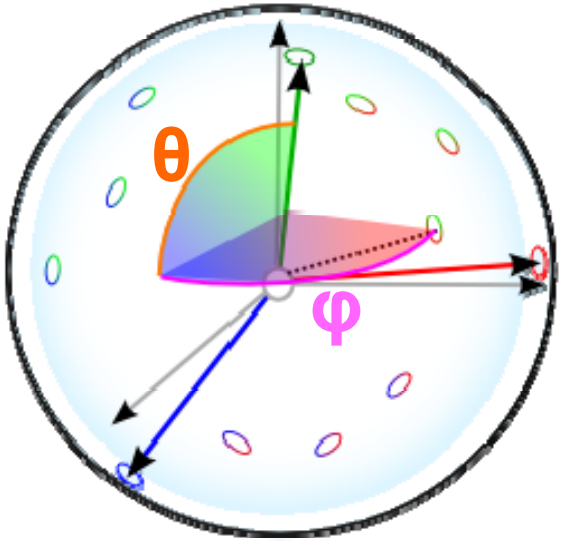
- Translate the mesh to origin
- Define local axes from surface particles



Building The Hash

Preprocessing step

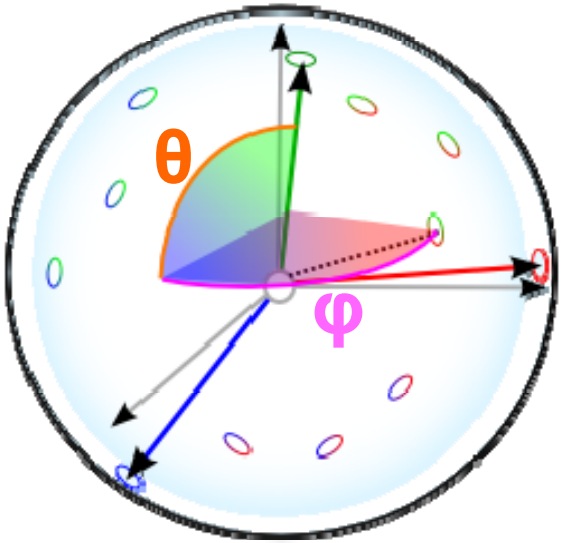
- Translate the mesh to origin
- Define local axes from surface particles
- Map to spherical coordinates

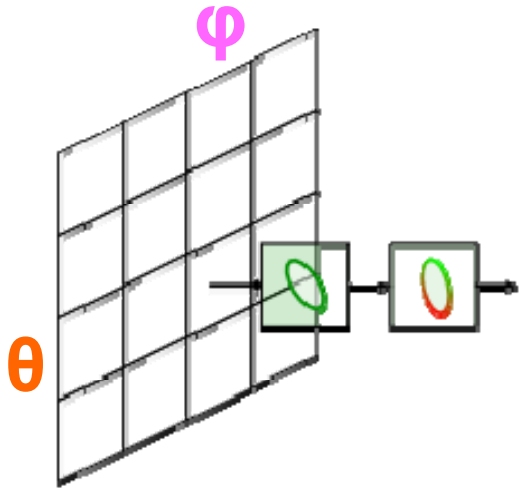


Building The Hash

Preprocessing step

- Translate the mesh to origin
- Define local axes from surface particles
- Map to spherical coordinates
- Map to the hash matrix[θ, φ]

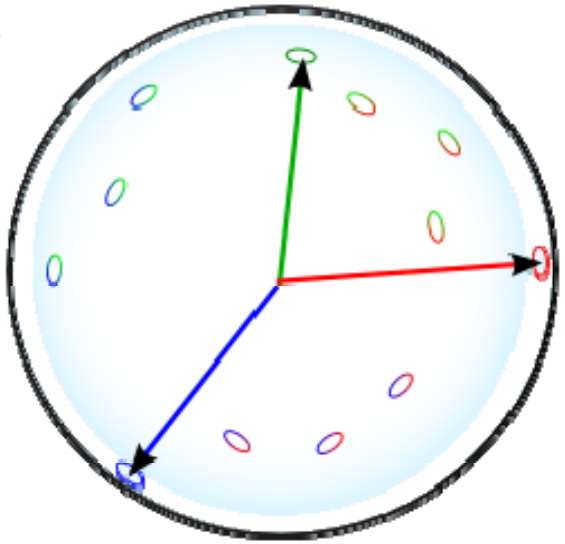


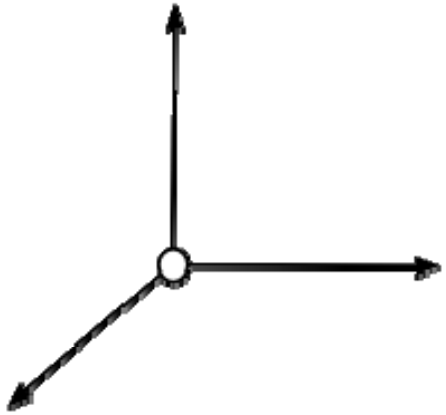


Building The Hash

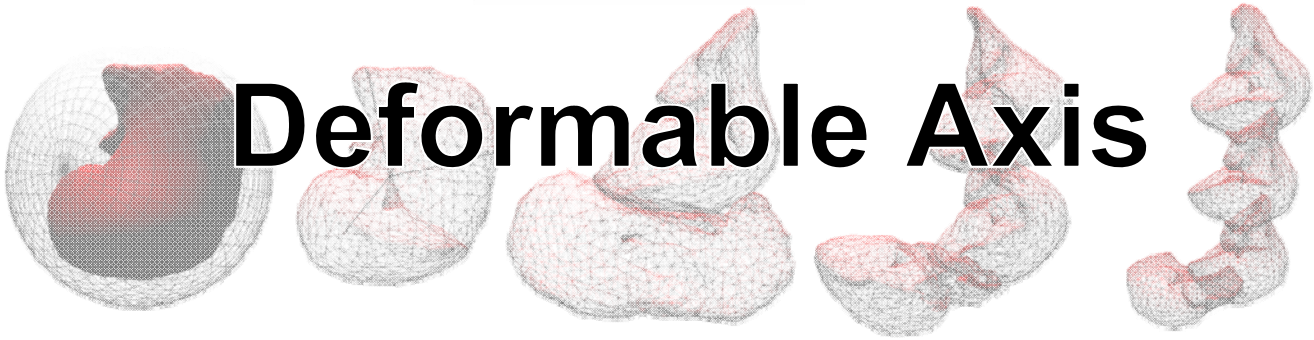
Preprocessing step

- Translate the mesh to origin
- Define local axes from surface particles
- Map to spherical coordinates
- Map to the hash matrix[θ, φ]
- Translate the mesh back

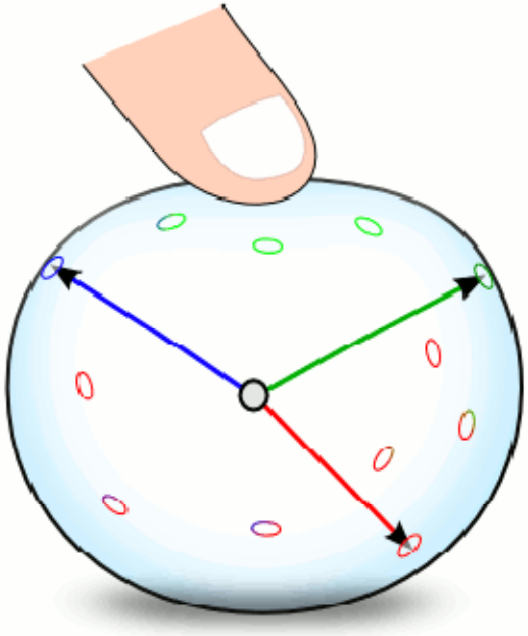




Deformable Axis



- The **local axes** will **deform with the mesh!**
  - Maintaining valid the mapping to the hash



The Local Spherical Hash

Collision Detection Algorithm

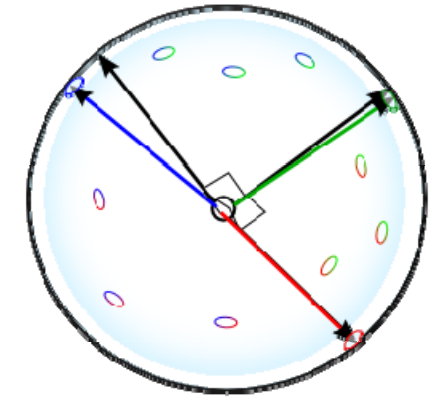
Pre Processing Step

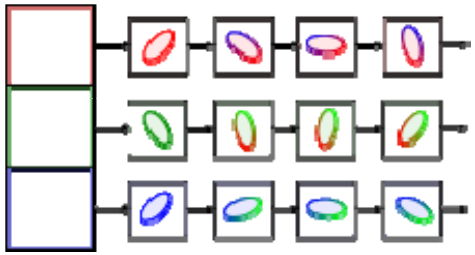
1º) Centralize

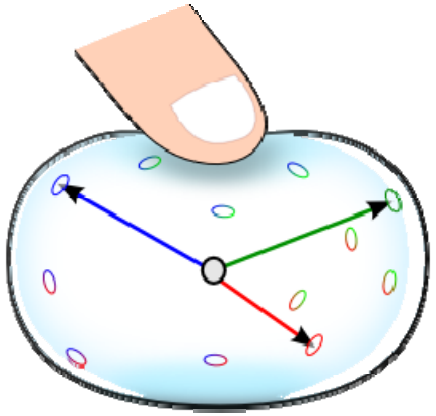
2º) Define local axis particles

3º) Map to spherical coordinates

4º) Map to Hash[θ, φ]







The **local axis** will **deform**

with the mesh!

The Local Spherical Hash

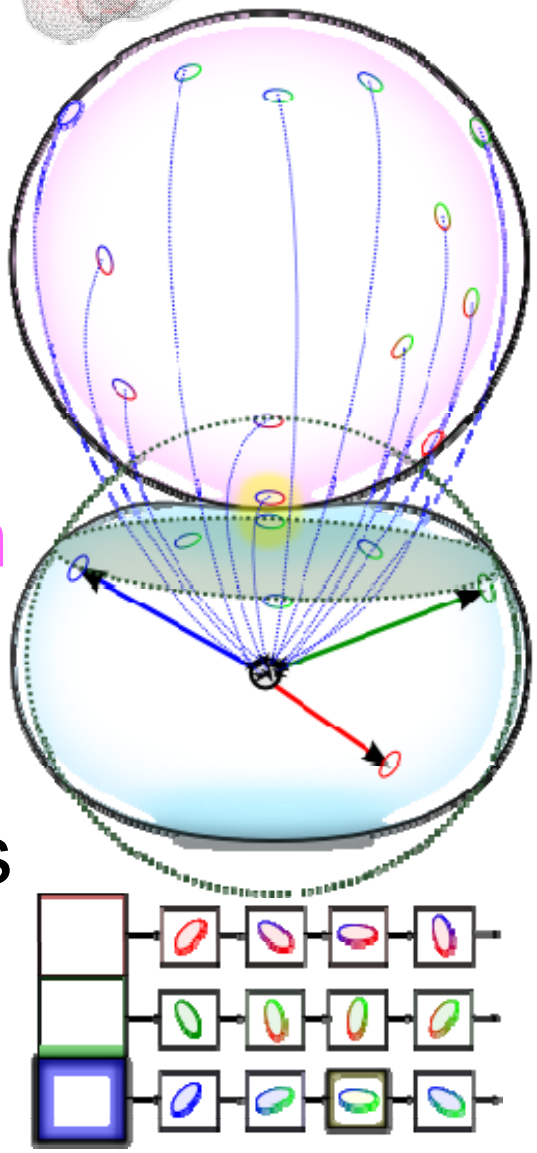
Collision Detection Algorithm

Collision Detection

1º) Test against the **Bounding Sphere**

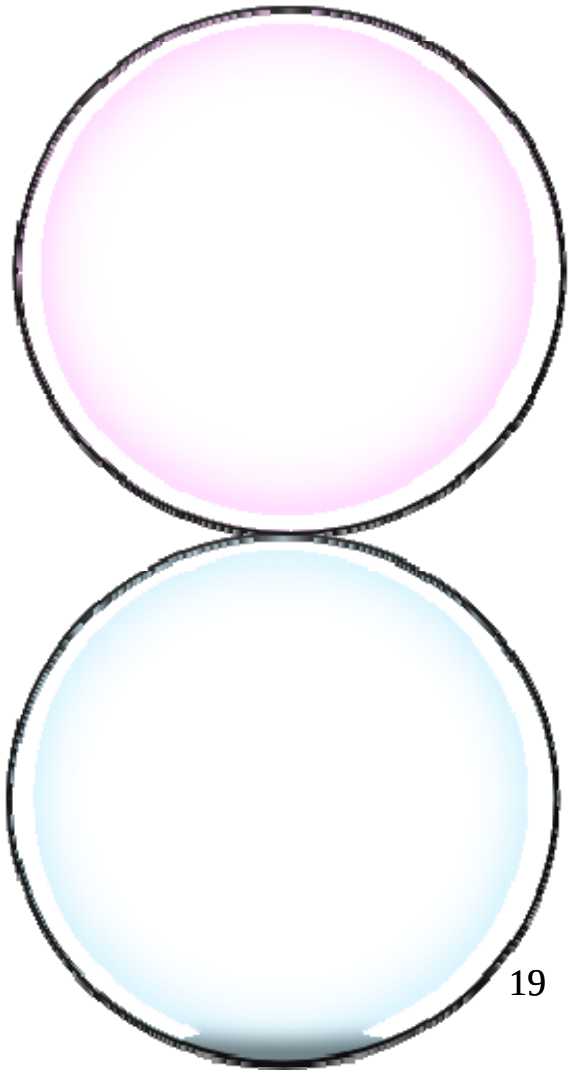
2º) Map particles **from one mesh** to the **other's LSH**

3º) Test **only** against the particles in the mapped solid angle



The Local Spherical Hash

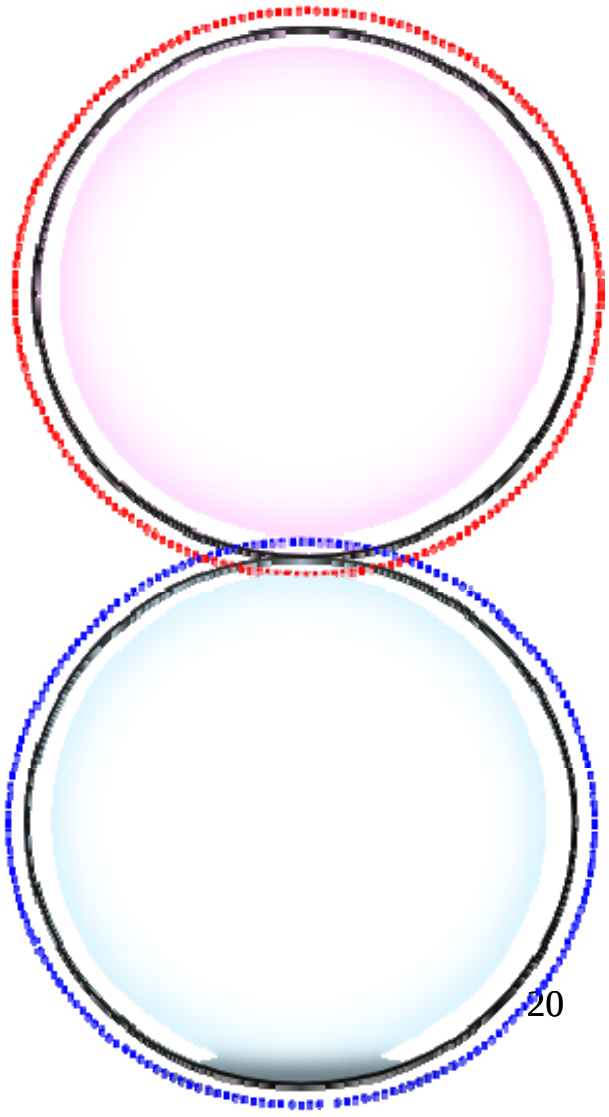
Collision Detection Algorithm



The Local Spherical Hash

Collision Detection Algorithm

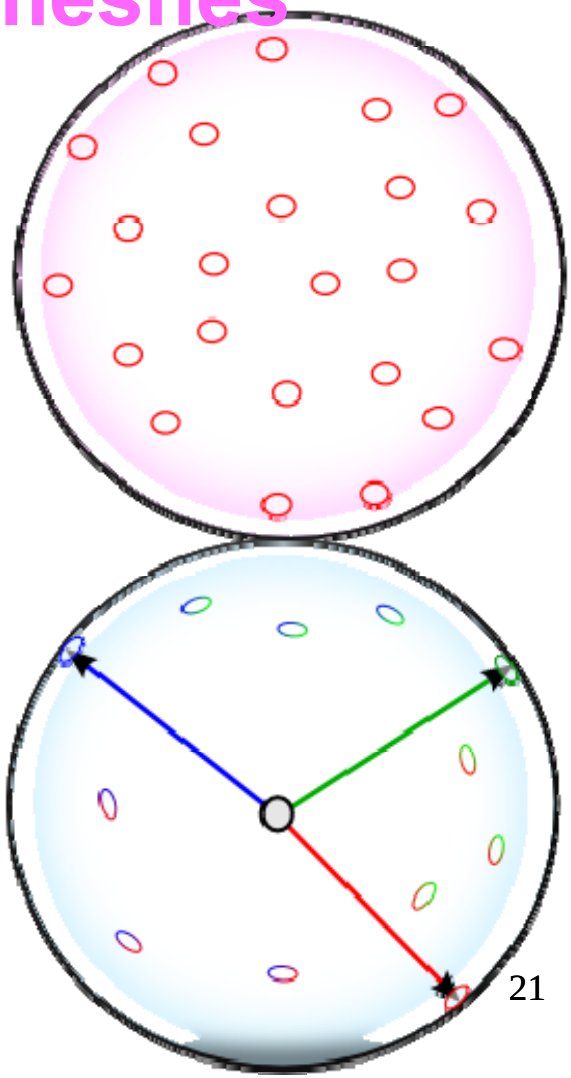
- Test against the **Bounding Sphere**



The Local Spherical Hash

Collision Detection Algorithm

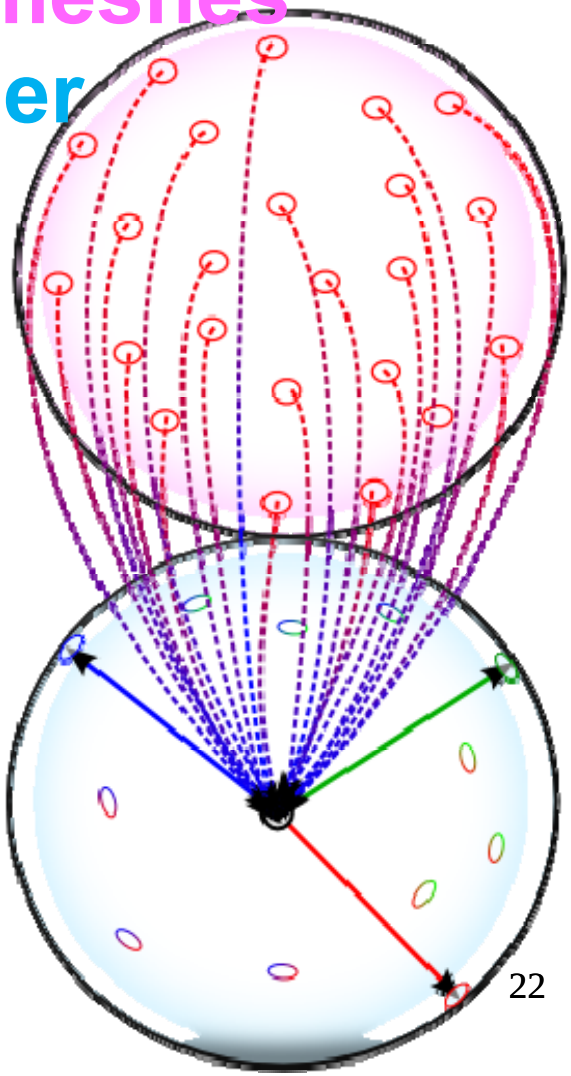
- Test against the **Bounding Sphere**
- Map particles **from one of the meshes**



The Local Spherical Hash

Collision Detection Algorithm

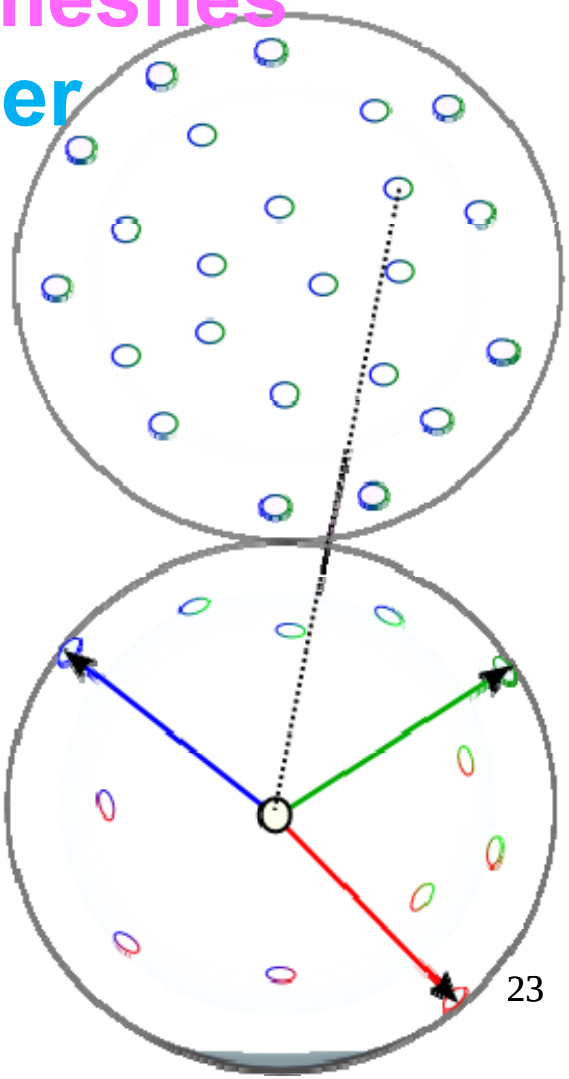
- Test against the **Bounding Sphere**
- Map particles **from one of the meshes** to the LSH of the **other**



The Local Spherical Hash

Collision Detection Algorithm

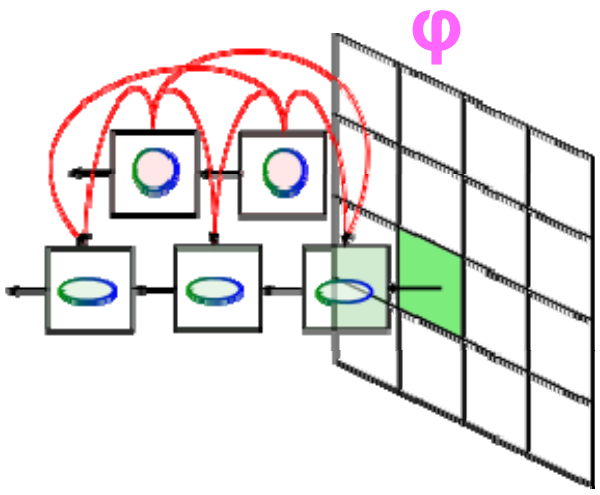
- Test against the **Bounding Sphere**
- Map particles **from one of the meshes** to the LSH of the **other**
- Test the particles **only** against

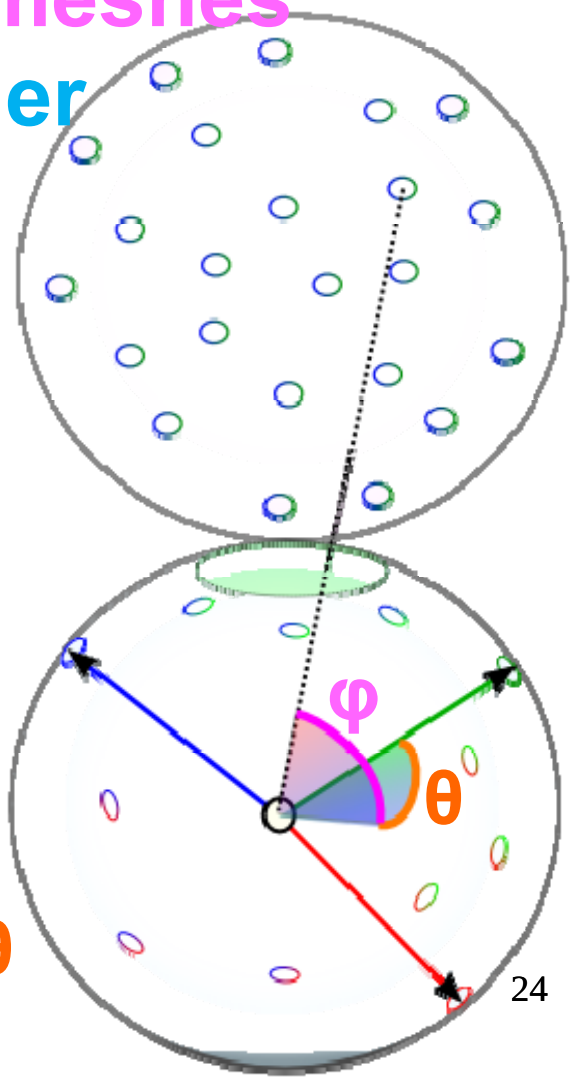


The Local Spherical Hash

Collision Detection Algorithm

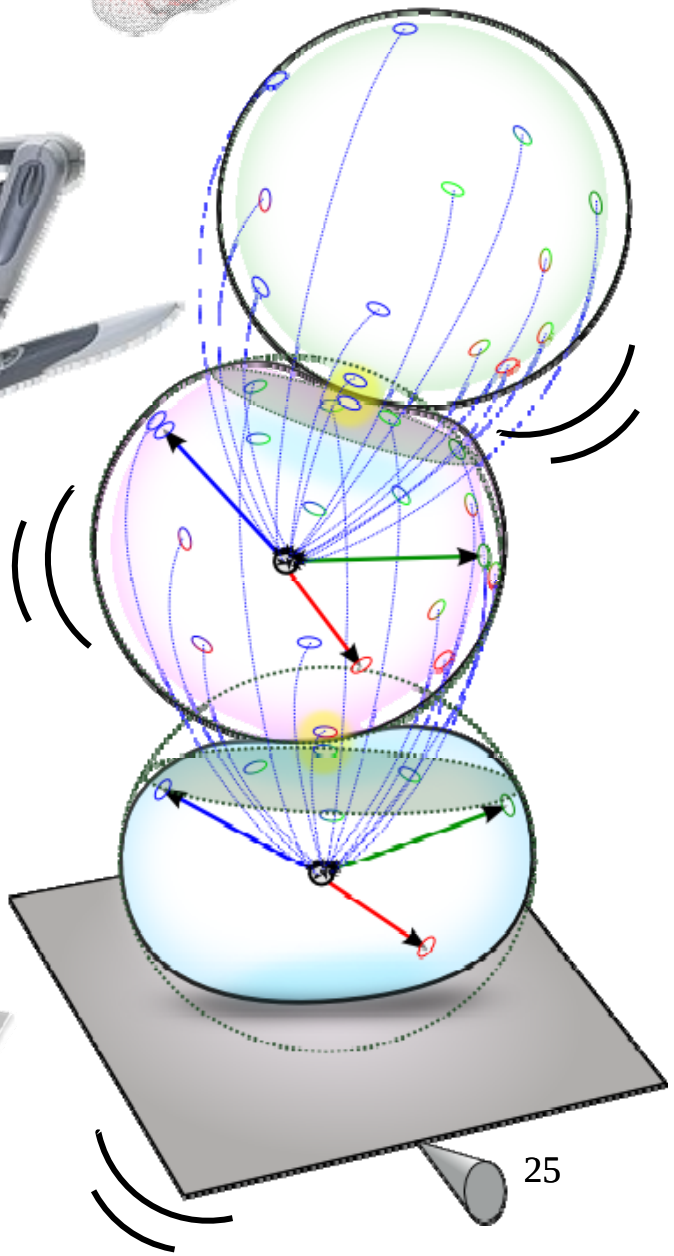
- Test against the **Bounding Sphere**
- Map particles **from one of the meshes** to the LSH of the **other**
- Test the particles **only** against those in the mapped hash entry

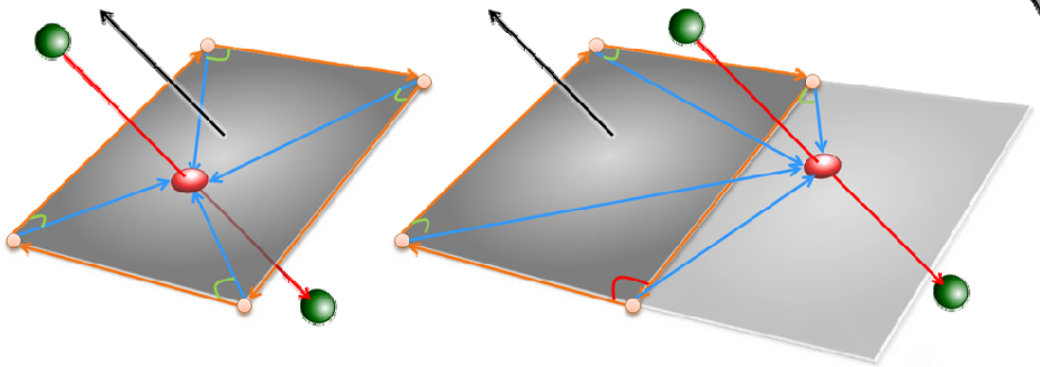


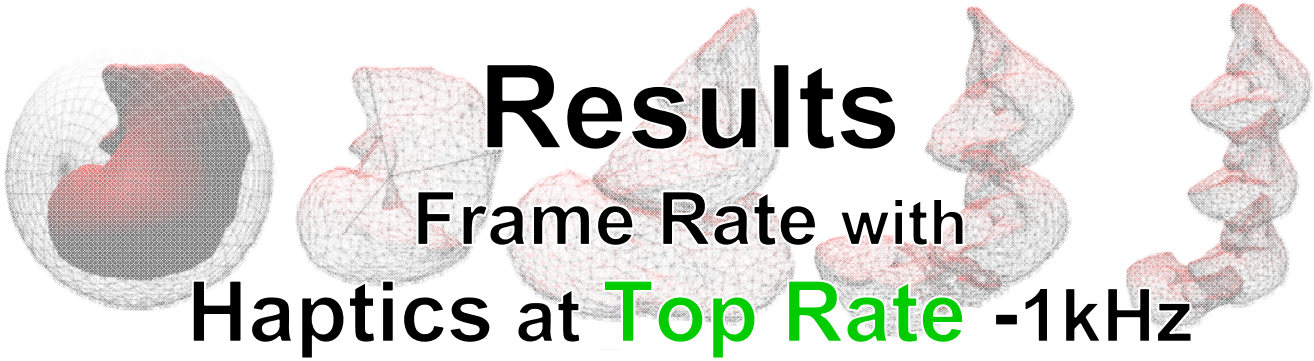


Haptics Interaction
Interaction Example

- Shovel tool
  - Phantom Omni device
  - Gravity
- Why?
  - Easy collision detection
  - Simple force feedback

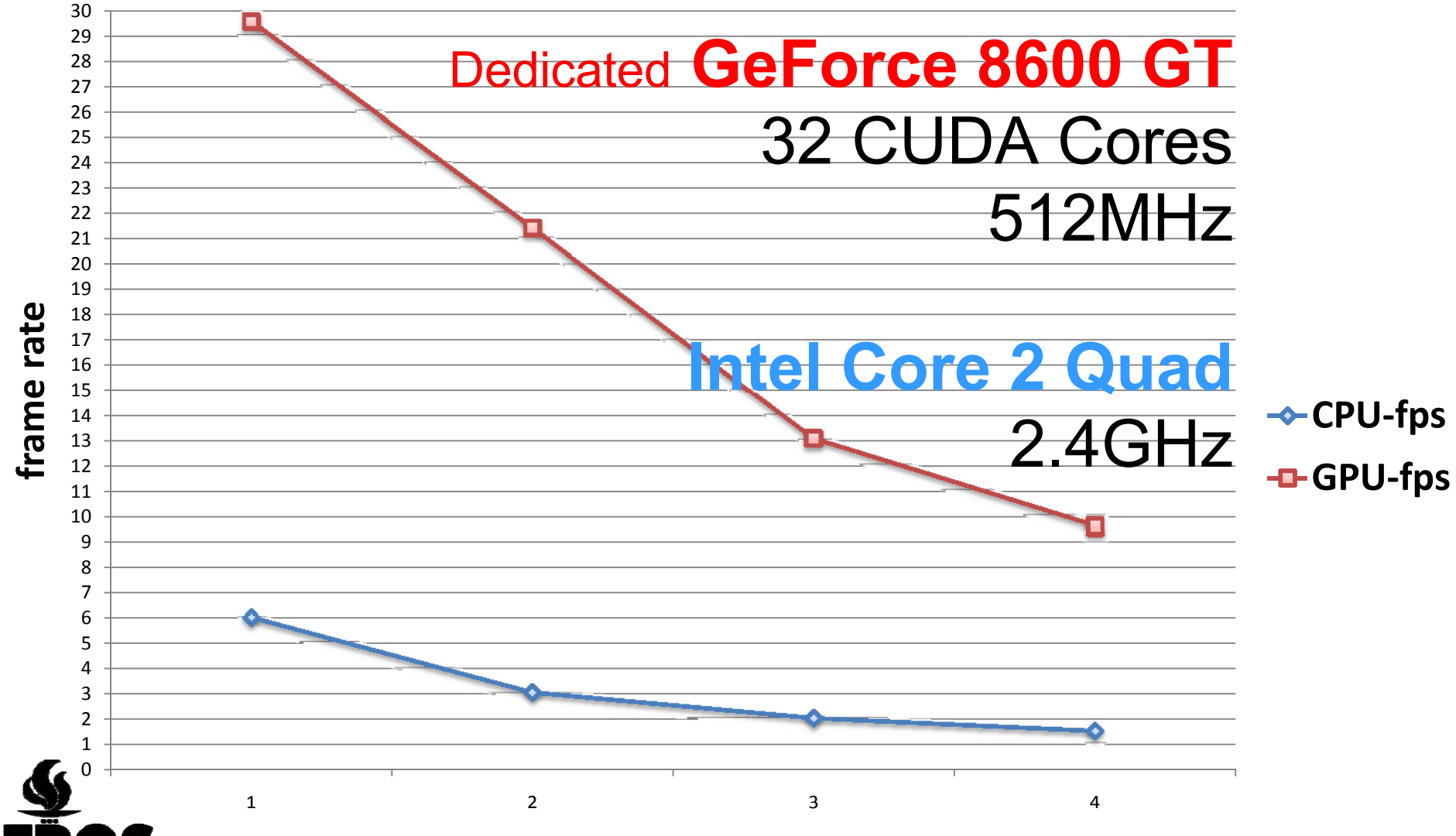






Results

Frame Rate with Haptics at Top Rate -1kHz



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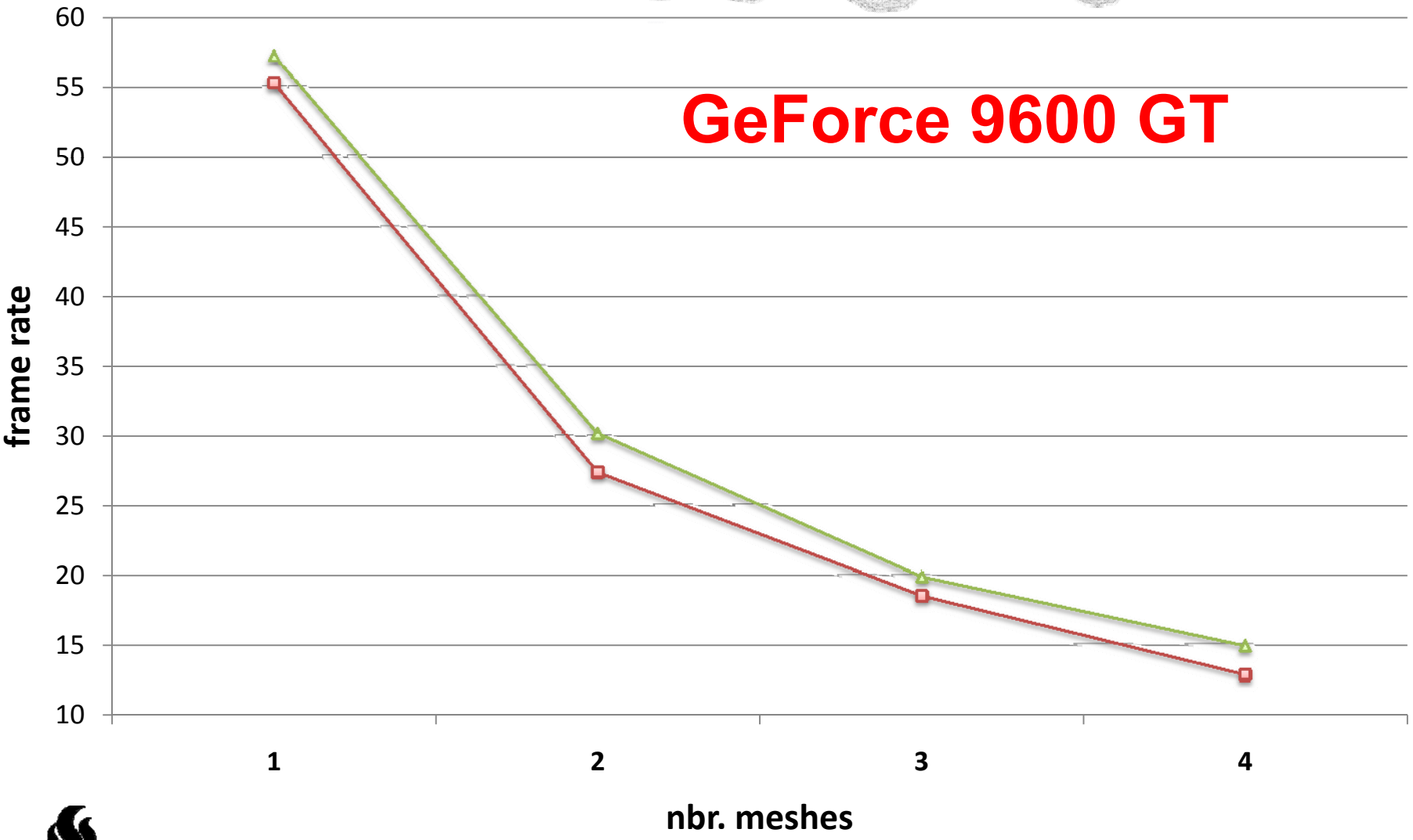
Results

LSH performance



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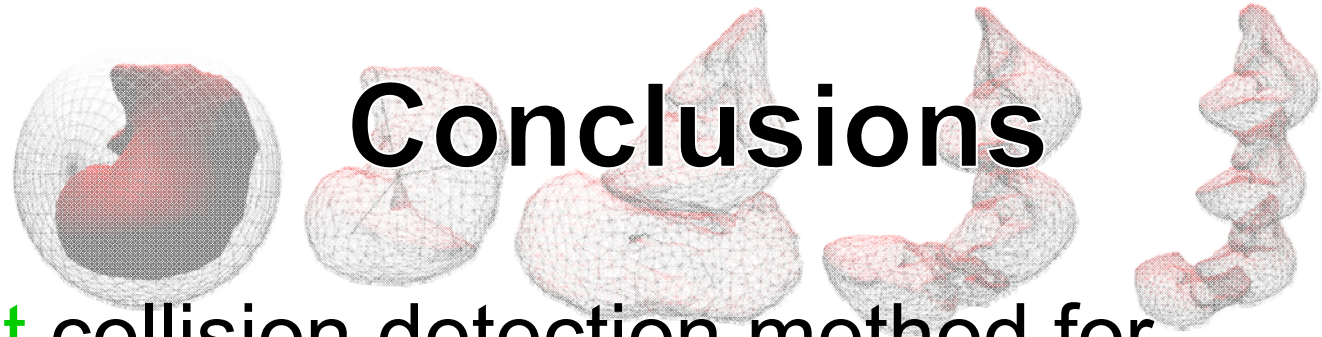
Limitations

- The LSH do not handle self-collision

- Crash Possibilities:
  - two of the basis vectors become linearly dependent (model is completely crushed);
  - two of the particles defining the basis invert positions (model is completely crushed);

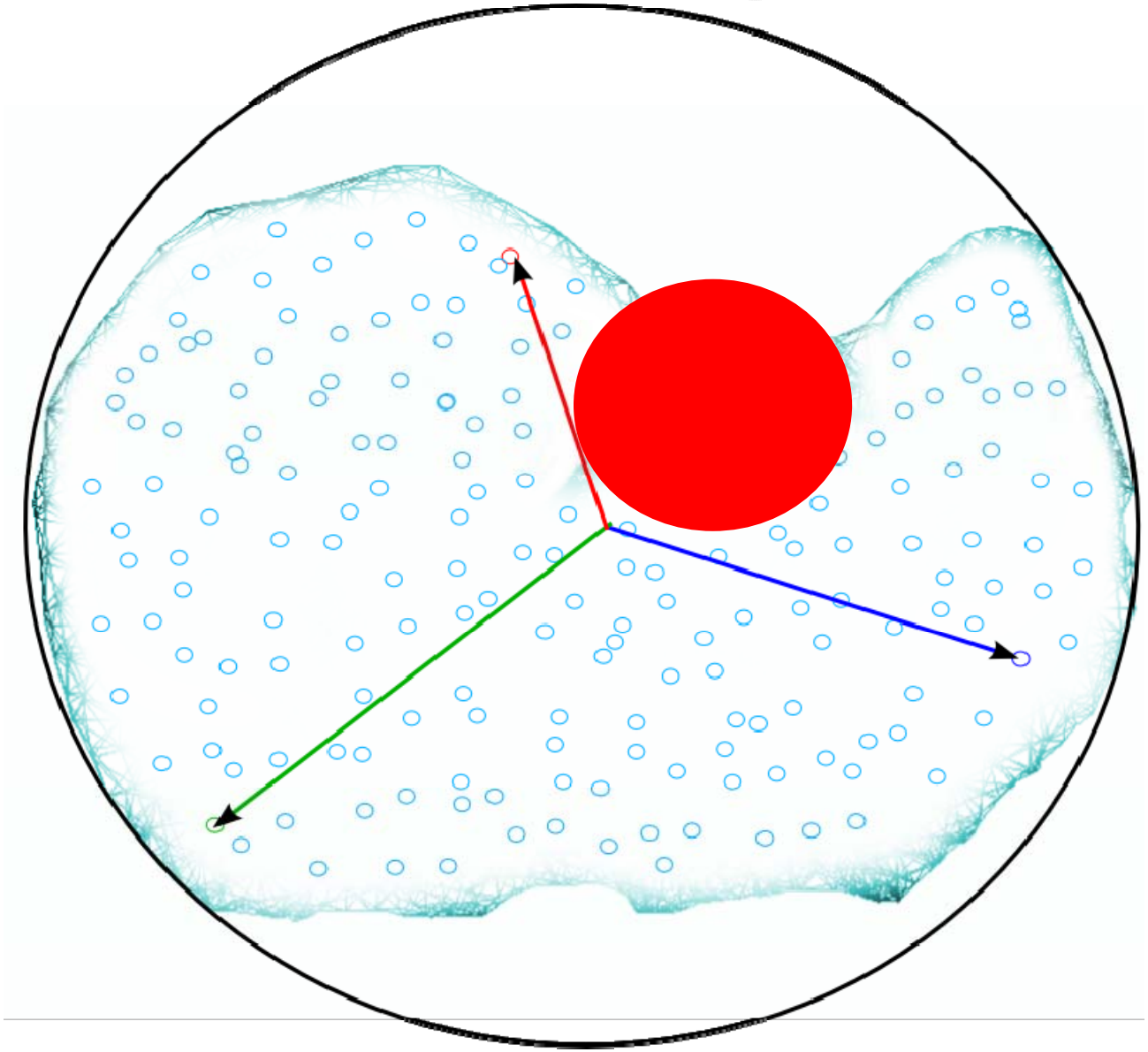


Conclusions

- Fast collision detection method for
  - Deformable models
  - Haptic feedback
- Efficient GPU implementation
- Mapping resolution will vary with frame deformation, but this can either improve or worsen a bit the detection quality.

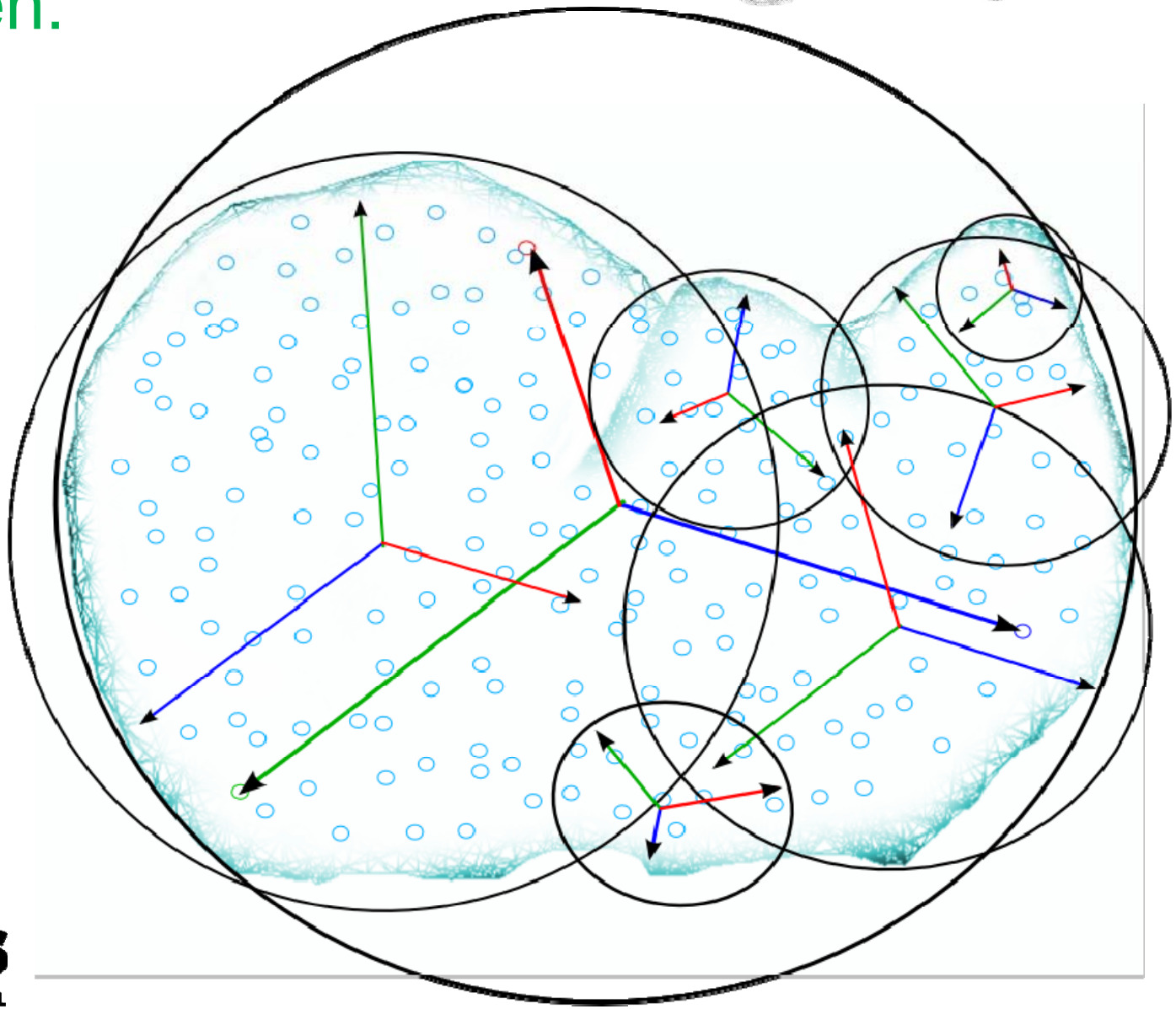
Future Work...

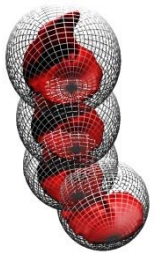
- Now:

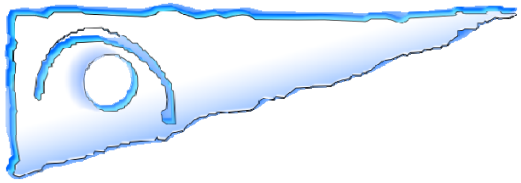


Future Work

- Then:







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