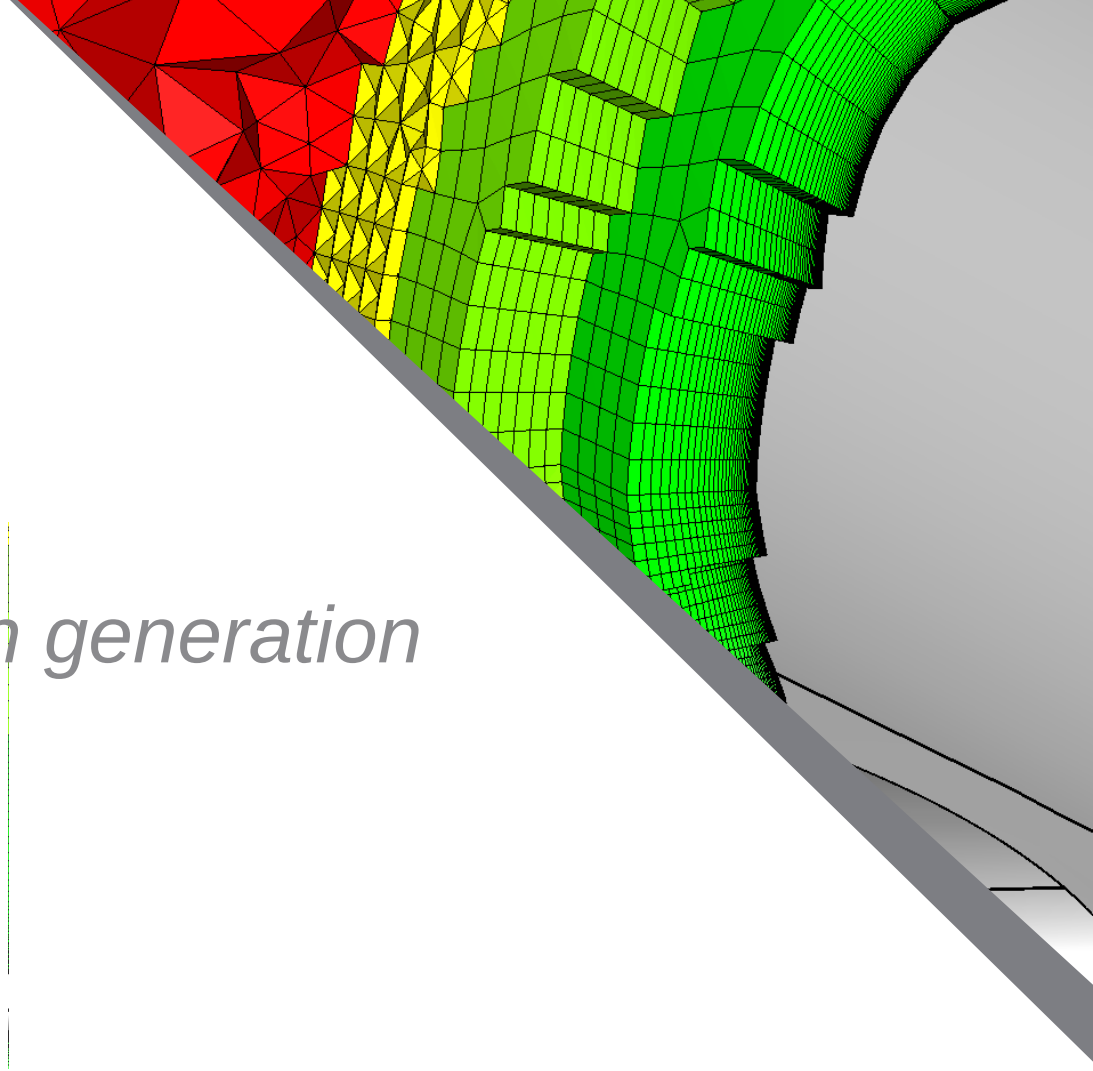
ITI
a wipro company



Geometry for mesh generation

ELEMENT 2020

Henry Bucklow

21st October 2020

Introduction

- ITI Ltd
  - Software company based near Cambridge
  - Suppliers of CADfix: a tool for translation, repair, and transformation of CAD models
  - CADfix is used as a pre-processor by key customers
  - 40+ years developing CAD, CAE, and meshing tools
- Multi-representation CAD engine
  - Traditional b-rep, medial axis, curved triangles, subdivision surfaces, level sets

Why is geometry still interesting?

- Dissatisfaction with status quo
  - MCAD b-rep in, mesh out
- Integration of solver/mesh/geometry
  - Solution adaptive mesh generation
  - Optimisation of geometry
  - Distributed geometry, mesh generation & solution

Representations

- Considering:
  - CAD boundary representation (b-rep)
  - Linear triangles
  - Curved triangles
  - Subdivision surfaces
  - Spatial occupancy/level sets
  - “Isogeometric” volumetric representations

Criteria

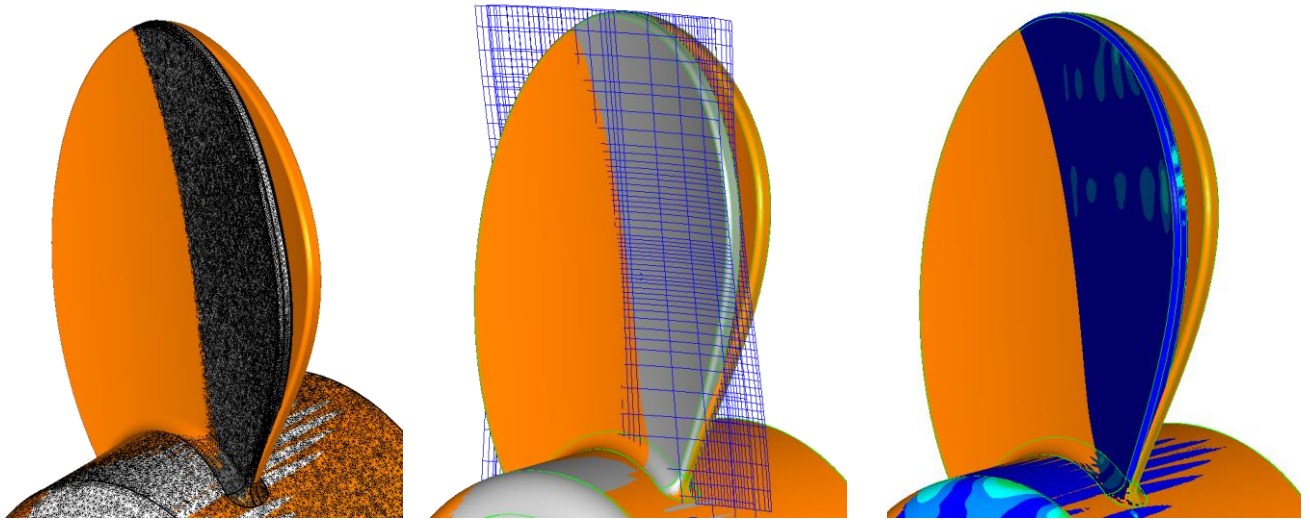
- Accuracy
- Memory usage
- Consistency
- Continuity
- Ease of manipulation
- Ease of construction
- Distributable?

MCAD boundary representation

- As output by design system: CATIA, NX, …
+ Accuracy, memory usage, continuity, ease of construction
  - Often considered “ground truth” geometry
  - Efficient (developed in 1970s)
  - Most common source of geometry (but quality varies!)

MCAD boundary representation

- Consistency, ease of manipulation
  - Boundary/interior mismatch
  - Hard (but not impossible) to manipulate

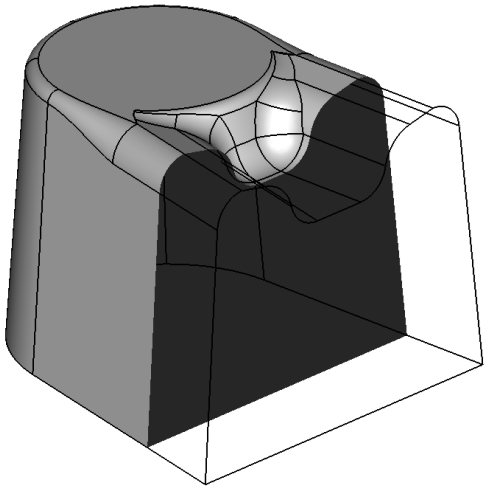


MCAD boundary representation

- Distributable?

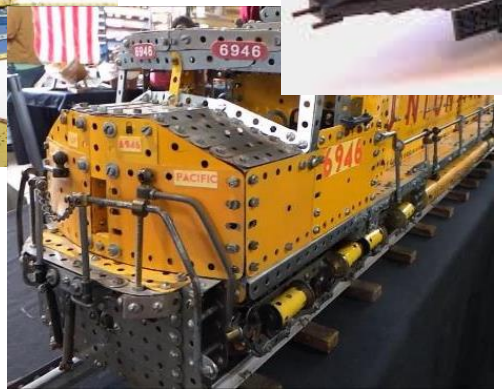
~~MCAD~~ boundary representation

- Just a hollow closed shell
  - No internal structure relating boundary pieces
  - No proximity/thickness data
  - Algorithms stumbling around in the dark



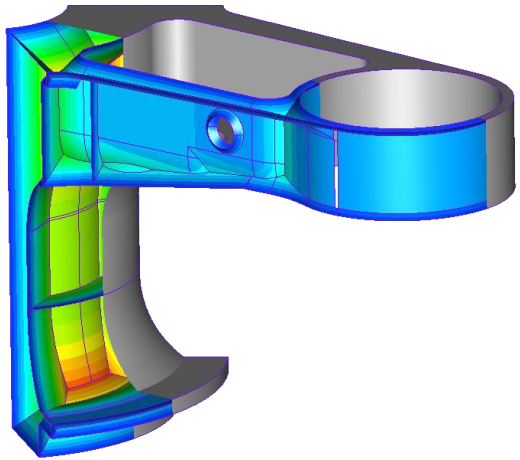
~~MCAD~~ boundary representation

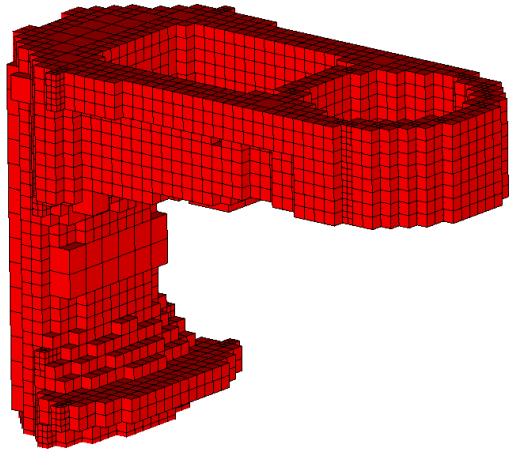
- It’s a dumb solid
  - Think Meccano not LEGO

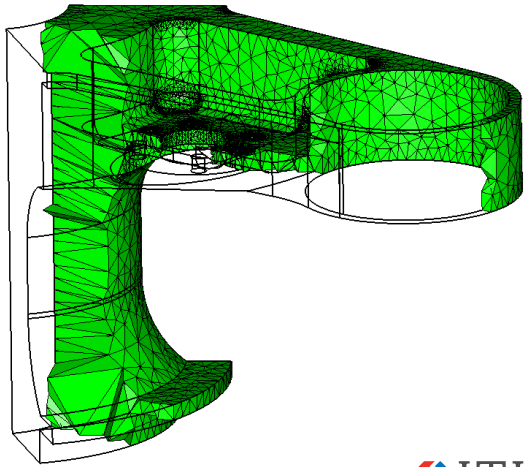


~~MCAD~~ boundary representation

- Distributable?
  - No help given for partitioning
  - External structures required (medial axis, spatial index, mesh …)







MCAD boundary representation

- Distributable?
  - \- Complexity of structure unhelpful
  - \+ Compact representation

Linear triangles

+ Consistency, ease of manipulation, ease of construction
  - No edge/interior mismatches (though may inherit issues from MCAD!)
  - Simple to manipulate
  - Easy to construct – may be “source” geometry for real-world data

The triangulated Stanford Bunny is a common example model

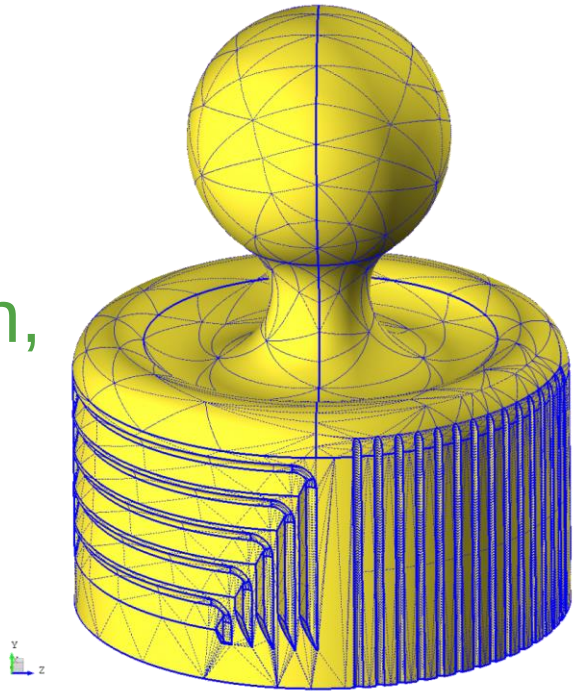
Linear triangles

- Accuracy, memory usage, continuity
  - Poor accuracy/memory usage trade-off
  - C0 continuity only
- Distributable?
  - Still a boundary representation
  + Simple to split up
  - Large data size

Curved triangles

- Cubic interpolating triangles
  - Point-normal
  - C1 curvature-continuous

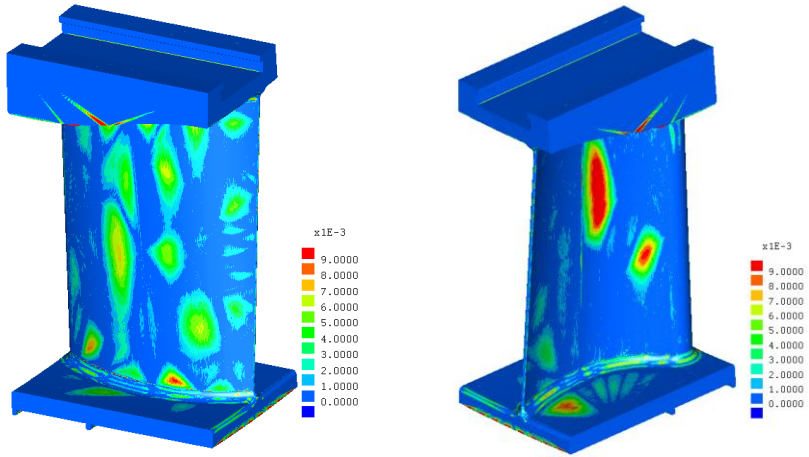
+ Consistency, ease of manipulation, ease of construction
  - Very similar to linear triangles
  - Triangle shape important



C1 curved triangulation

Curved triangles

- Accuracy, memory usage, continuity
  - Accuracy/memory usage trade off much better
  - C1 continuity between triangles achievable



Two triangulations with same max. error.
Left: linear triangulation with 47000 tris

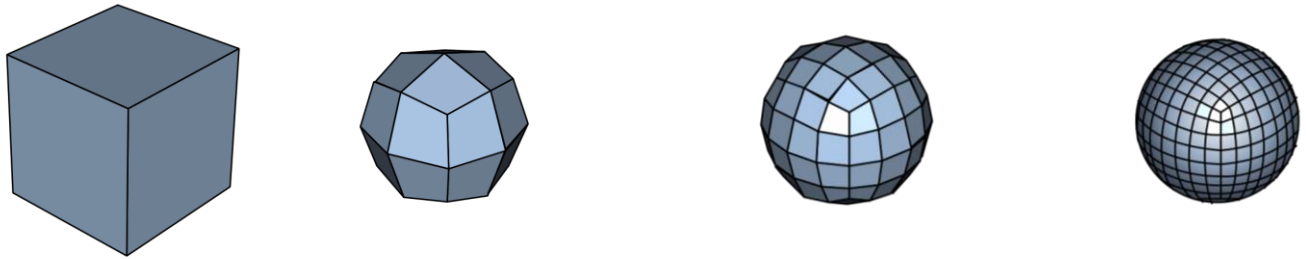
Right: C1 triangulation with 3500 tris

Curved triangles

- Distributable?
  - \- Still a boundary representation
  - \+ Simple to split up
  - More compact than linear triangles, less compact than MCAD

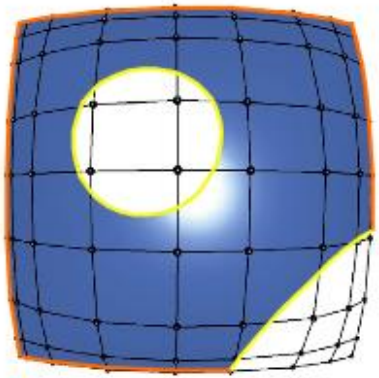
Subdivision surfaces

+ Accuracy, memory usage, consistency, continuity, ease of manipulation
  - Depending on scheme, capable of accurate MCAD representation with similar weight
  - No boundary/interior inconsistency
  - Simple structure to manipulate geometry

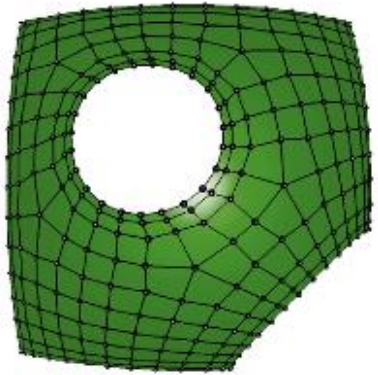


Subdivision surfaces

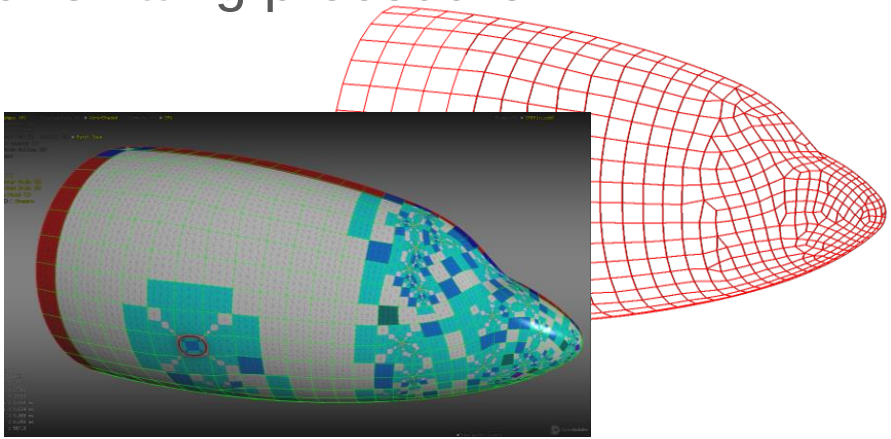
- Ease of construction
  - Best schemes require quad grid
  - Approximating schemes require fitting procedure



Trimmed NURBS



Subdivision surface

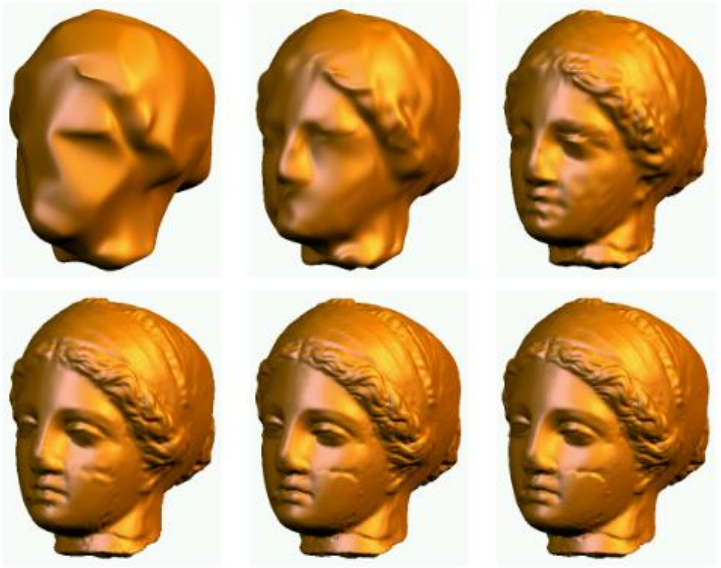


Catmull-Clark subdivision made from quad-dominant mesh

ITI

Subdivision surfaces

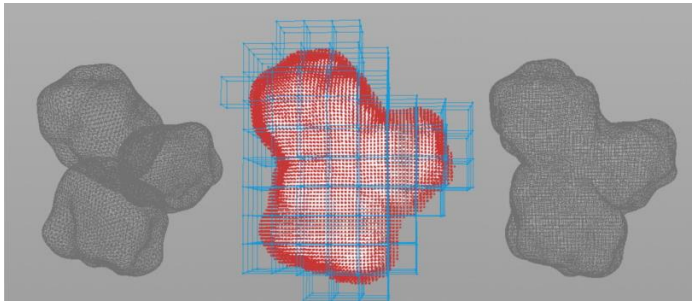
- Distributable?
  - \- Still a boundary representation
  - \+ Potential for multiresolution representation (wavelet decomposition)
  - \+ Compact representation (depending on construction!)



Multiresolution representation using biorthogonal Loop subdivision wavelets

Spatial occupancy/level sets

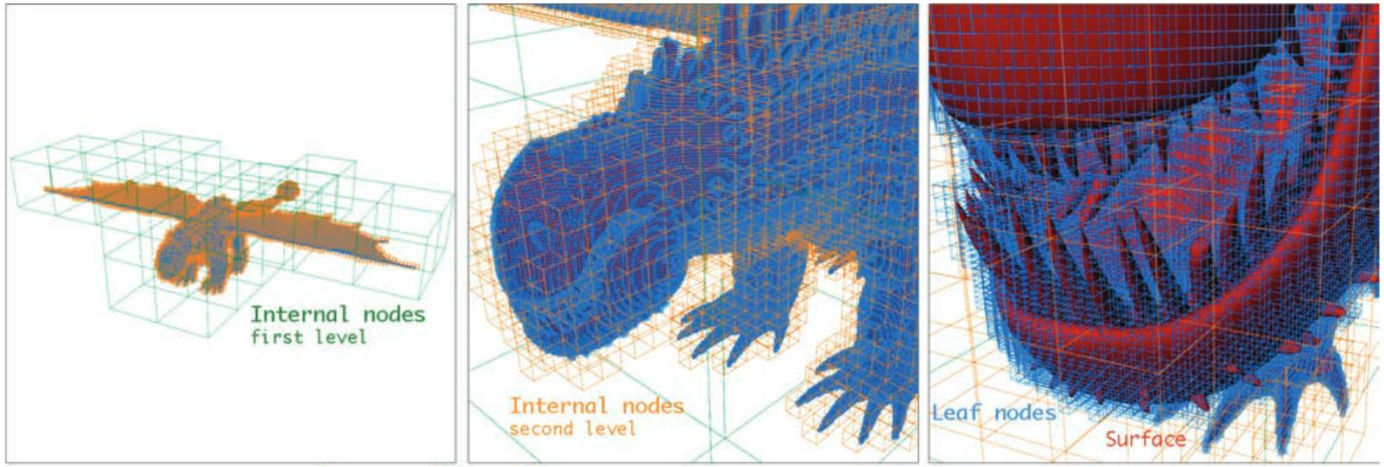
- True volumetric representations
+ Ease of manipulation, Ease of construction, Consistency
  - Simple, topology-free manipulation
  - Can embed b-rep within signed distance field



OpenVDB level set created around b-rep mesh

Spatial occupancy/level set

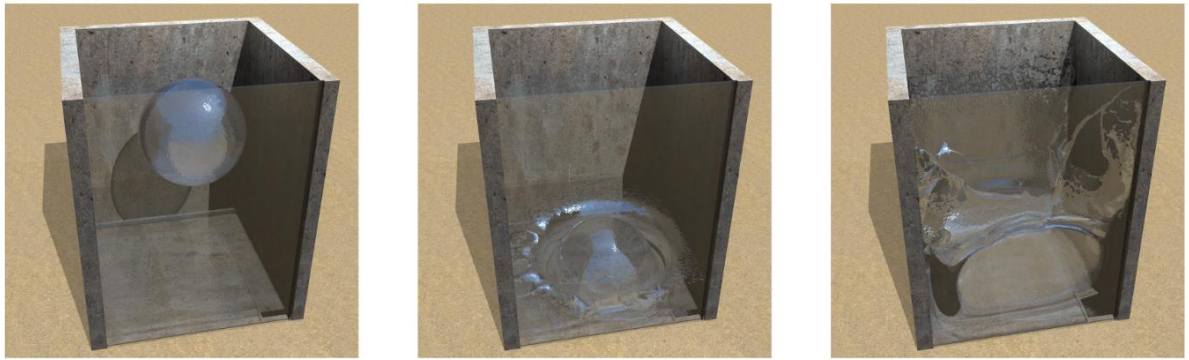
- Accuracy, Memory usage, Continuity
  - Accuracy vs memory usage can be difficult
  - Continuity not easily available



1GB memory required to hold this VDB model

Spatial occupancy/level set

- Distributable?
  - + Volumetric! Native spatial structures (octree, VDB) can help decompose meshing problem, provide natural decomposition strategies
  - - Data size can be large



Sphere drop simulation using OpenVDB on a distributed architecture

Mixing representations

- Not restricted to a single representation
  - MCAD b-rep can be mixed with other types
- Use curved triangulation as proxy
  - Add trimming and UV parameterisation to subdivision, level set geometry

Conclusions

- B-reps need help for distributed applications
  - Something to describe the volumetric structure
- Volumetric representations have hard trade-offs
  - Heavyweight/limited accuracy or hard to construct
- Promising “sweet spot” for consistent, modifiable geometry: curved triangles or subdivision surfaces

ITI
a wipro company

Thank you!