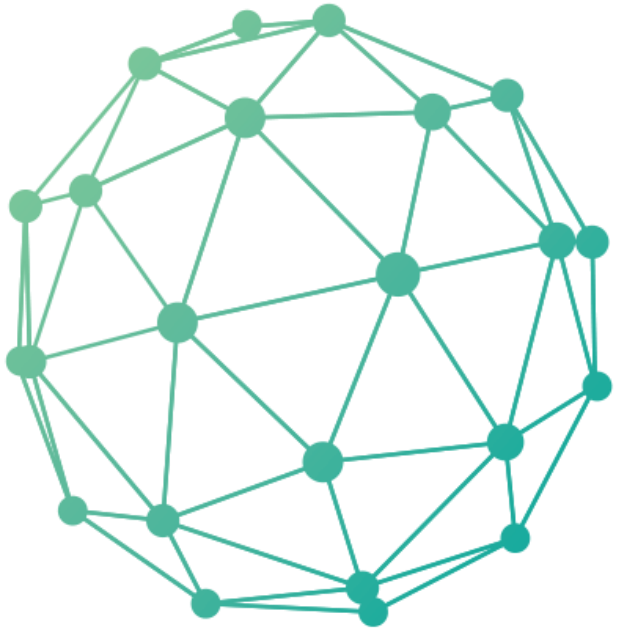


ELEMENT

Mesh interaction & visualisation

Mesh interaction

- “interaction” here might cover a broad range of topics
  - visualisation
  - analysing/inspecting (e.g. for quality checks)
  - moving
  - modifying
- Not part of the simulation per se, but potentially an important aspect of the overall workflow

Visualisation

- Visualisation algorithms themselves are generally embarrassingly parallel
  - Processes operate on their own portions of the data
  - Although rendering step is an “all reduce” type operation sending scene data to the display system [1]
- High I/O and memory performance necessary (both high bandwidth and low latency), coupled with GPU-backed rendering
  - Can support accurate and fast visualisation up to the point where the hardware is saturated
  - In-situ approaches can resolve the I/O issue
- Some existing solutions: Paraview, VisIT, Catalyst, Damaris

[1] Childs H, Pugmire D, Ahern S, Whitlock B, Howison M, Prabhat, et al. Extreme Scaling of Production Visualization Software on Diverse Architectures. IEEE Comput Graph Appl. 2010 May;30(3):22–31.

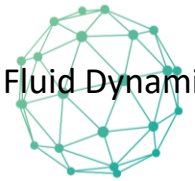
Limitations

- Interaction is limited by hardware capacity and capability
  - Limits are reached quickly for very large meshes
  - Interaction becomes too slow/cumbersome to be of value
- Specialist hardware can push the limitations to larger scales, but moving the meshes is not desirable
- “Black blob” problem
  - Not enough pixels and too many points to show all the details of the mesh

Fundamental questions

- Do we need to be able to visualise meshes of any size?
- Is this a “nice to have” or “need to have” feature?
  - i.e. “vital for the Exascale workflow” or “a means to an end” [2]
  - Balancing practical necessity in the short term with long term ideal
- Is there (or can there be) a universal metric for a “good” mesh?
  - Necessary for taking the human out of the loop
    - Enable users to provide their own metric
  - Different discretisations (FEM, FVM, …)
  - High-order discretisations
    - Curved elements *etc.*

[2] Chawner JR, Dannenhoffer J, Taylor NJ. Geometry, Mesh Generation, and the CFD 2030 Vision. In: 46th AIAA Fluid Dynamics Conference [Internet]. Washington, D.C.: American Institute of Aeronautics and Astronautics; 2016



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Goals and potential research areas

- *Ultimate* goal may be to eliminate the need to view a mesh
- However from a practical perspective visualisation might remain a necessity for some time
- Two general approaches that could be explored
    1. Working with subsets or “views” of a mesh
    2. Adaptive/multi-level resolution, analogously to the “Level of Detail” method used in computer games [3][4][5]
        a) Similar idea used for lossy-compression of scientific data storage: https://github.com/CODARcode/MGARD
        b) Level of Detail replaces high-resolution data with low-resolution representation when too far to see

Hoppe H. Progressive meshes. In: Proceedings of the 23rd annual conference on Computer graphics and interactive techniques - SIGGRAPH ’96 [Internet]. Not Known: ACM Press; 1996 [cited 2021 May 14]. p. 99–108. Available from: http://portal.acm.org/citation.cfm?doid=237170.237216

Hoppe H. View-dependent refinement of progressive meshes. In: Proceedings of the 24th annual conference on Computer graphics and interactive techniques - SIGGRAPH ’97 [Internet]. Not Known: ACM Press; 1997 [cited 2021 May 14]. p. 189–98. Available from: http://portal.acm.org/citation.cfm?doid=258734.258843

Hoppe H. Smooth view-dependent level-of-detail control and its application to terrain rendering. In: Proceedings Visualization ’98 (Cat No98CB36276) [Internet]. Research Triangle Park, NC, USA: IEEE; 1998 [cited 2021 May 14]. p. 35-42,. Available from: http://ieeexplore.ieee.org/document/745282/

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Working with subsets of a mesh

- Solutions for interacting with subsets of a mesh should be feasible to get working in the short term
  - Building on similar technology for partitioning problems, already mature in numerical software
- The data structure and format of the mesh should be considered
  - For example, should a mesh be considered as multiple connected regions from the outset?
  - Doing so would remove the requirement for a hypothetical visualisation tool to load the entire mesh to extract a subset
  - Similarly could ease loading a mesh into a simulation at scale
- Data formats already in wide use such as HDF5, BP4 could already support such an approach

Adaptive resolution

https://en.wikipedia.org/wiki/Level_of_detail_(computer_graphics)

Visual impact comparisons and measurements

Image					
Vertices	~5500	~2880	~1580	~670	140
Notes	Maximum detail, for closeups.				Minimum detail, very far objects.

- Basic idea: provide a “zoomable” view, from coarse to fine
  - Computer graphics use this technique in games
  - Also used for maps
- Coarsest view gives an outline that is quick to manipulate
- Zooming to specific areas means not all of the mesh needs to be visualised
- Potentially challenging… needs to be smooth & fast and might still require significant amounts of memory
  - Low resolution “zoomed out” view essentially compressed data – minimise communications for rendering step

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