Simplifying Unstructured Grids for Oceanographic Visualizations

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Oceanbox

- Tromso-based
- Interactive oceanographic simulations
- Oceanography as a Service
- Web-Based Geographic Information System (Web GIS)
- Digital twin of the coastal ocean

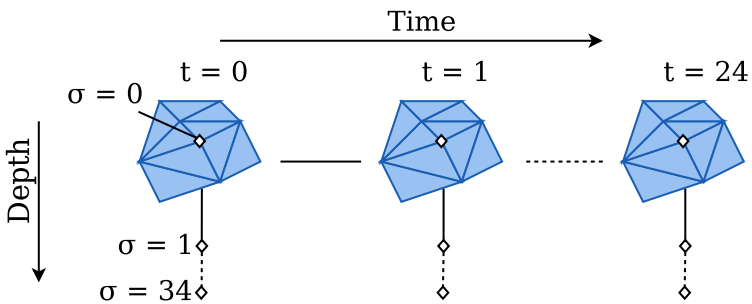
The Problem

- Large data sets
  - High resolution (millions of spatial points)
  - Multi-dimensional
  - Payloads of 20Mb+
  - Unresponsive web application
  - Increased bandwidth costs

The Solution: Lossy Compression

- Traditional approaches tricky
  - Accuracy of coordinates are important
  - Tiling/Multi-resolution not trivial with *unstructured grids*
  - Inflated data size should be smaller on the client
- Grid simplification
  - Remove vertices/nodes
  - Maintain visualization quality
  - **Angle bound half-edge collapse**

FVCOM grids



- Unstructured grid
  - Variable resolution
- Multiple dimensions
  - Coordinates, depth, time

Related Work

Rasterization-based approaches

- Good compression rates (90%)
- Requires *structured* grid layout

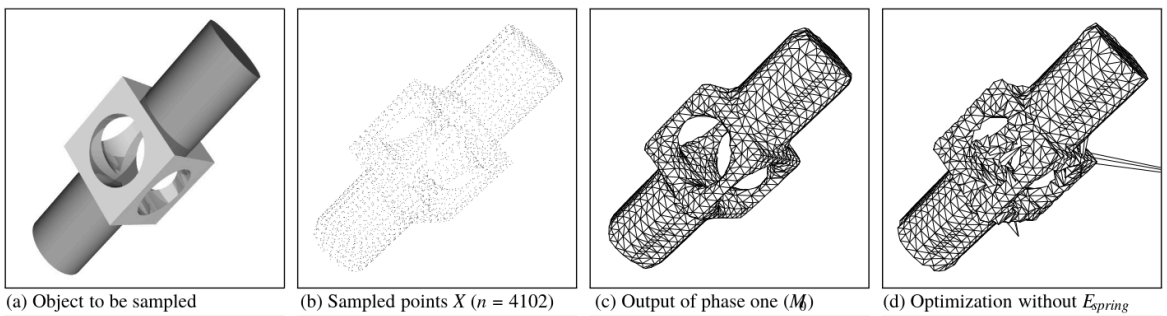
Tiling approaches

- Load only what you need
- Varying resolution
- Also requires structured grids

Mesh simplification

- More suited for unstructured grids
- Popular in literature: *3D mesh decimation*
- Not necessarily directly applicable…

Related Work: Mesh Simplification



(a) Object to be sampled (b) Sampled points X (n = 4102) (c) Output of phase one (M_0) (d) Optimization without E_{spring}

(e) Optimum for fixed K_0 (f) Optimum with $\kappa = 10^{-2}$ (g) Optimum with $\kappa = 10^{-3}$ (h) Final optimum with $\kappa = 10^{-8}$

- Approximate a surface[1]
- Preserve topology
- Good reduction

However

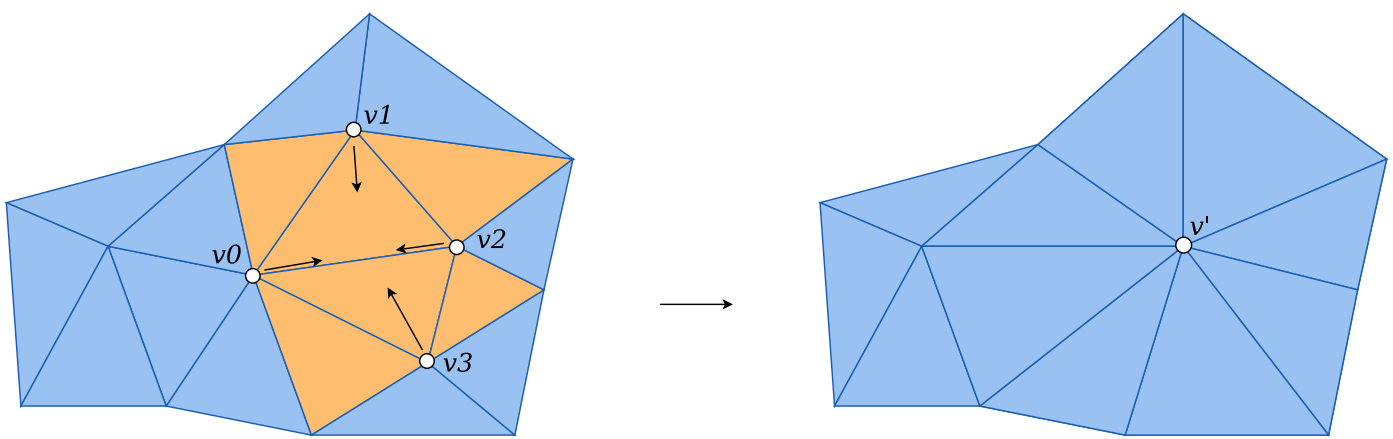
- Not ideal for 2D grids
- Need even resolution

[1]Figure from Hoppe et al. “Mesh Optimization”, *ACM*, 1993, pp. 19-26

Related Work: Mesh Simplification Operators

Vertex Clustering

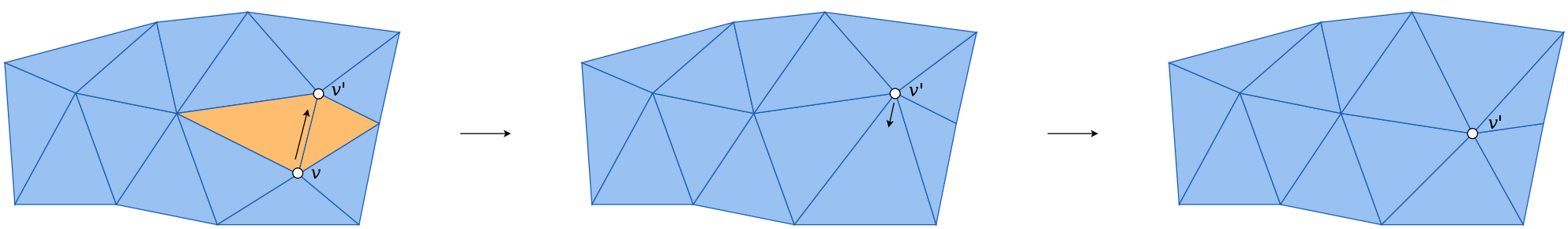
Identify a “cluster” of vertices and represent them all with one vertex



Related Work: Mesh Simplification Operators

Edge Collapse

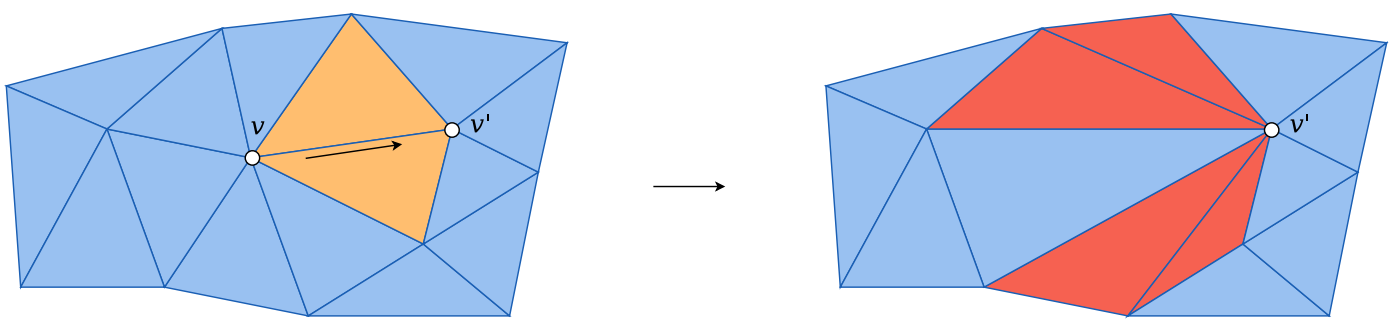
Collapse an edge between two vertices, representing them with one vertex



Our Approach: Angle Bound Half-edge Collapse

Adaptation from previous work.[1]

Half-edge collapse with a minimum angle criterion to inner angles



[1]Hinderink et al. “Angle-Bounded 2D Mesh Simplification.” *Computer Aided Geometric Design*, vol 95, May 2022, p. 102085

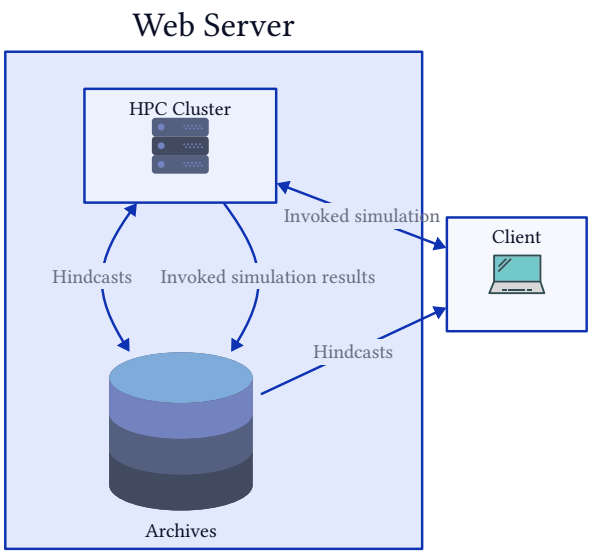
Architecture Overview

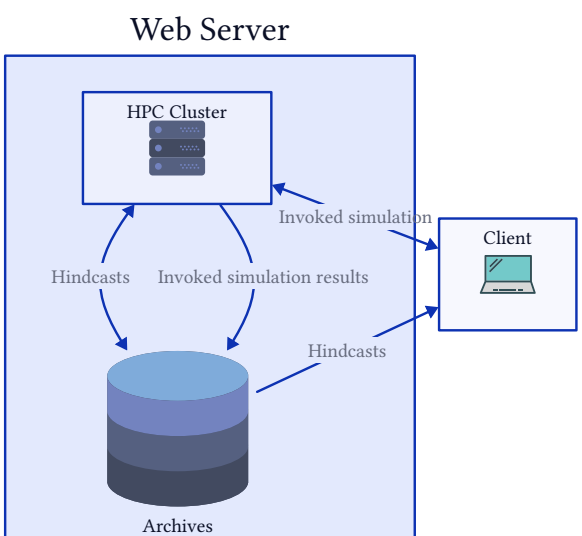
We concentrate on the data flow of *Archives*.

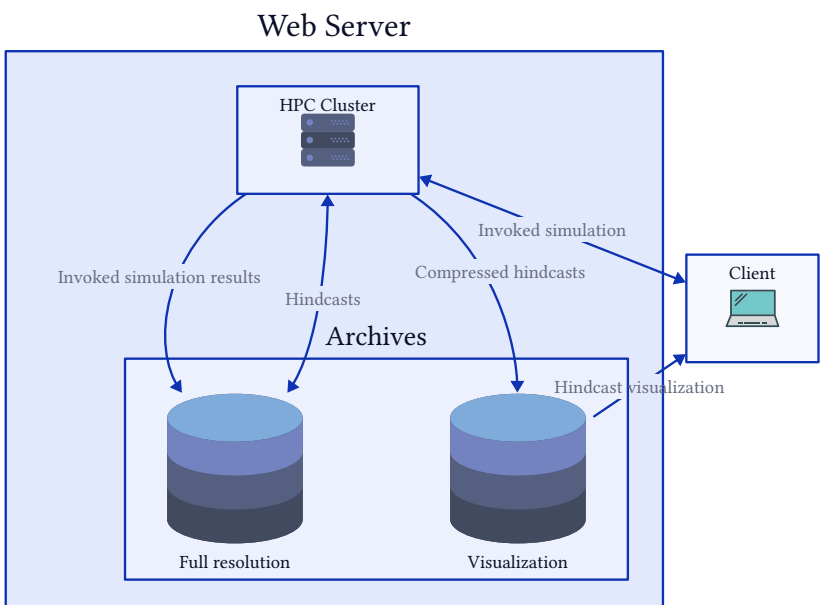
- *Hindcast* simulations
- *User invoked* simulations

Hindcasts are periodically produced, and are the basis of visualizations.

These are the archives we aim to compress/ reduce.




Web Server
HPC Cluster
Invoked simulation
Client
Hindcasts
Invoked simulation results
Hindcasts
Archives


Web Server
HPC Cluster
Invoked simulation
Invoked simulation results
Hindcasts
Compressed hindcasts
Client
Archives
Hindcast visualization
Full resolution
Visualization