Fast Adaptive Hybrid Mesh Generation
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Overview

1 Motivation

2 Our Technique
   Initial Background Grid
   Spatial Decomposition
   Buffer Zone

3 Results
   3-part Airfoil
   NACA Airfoil
   2-Vertical Cylinders
   Turbulent Flat Plate

4 Recent Development
Motivation: Structured Vs Unstructured Grids

Structured Grid
- Line Relaxation Solvers.
- Structured Multigrid Solvers.
- Comparatively Inexpensive.
- Relatively Simple Geometries !!
- Adaptation using Quadtree Methods !!
- Grid quality !!

Unstructured Grid
- Complex geometries.
- Isotropic Elements.
- Agglomeration Multigrid Solvers!!
- Block Relaxation Solvers!!
- More Expensive!!
- Adaption usually requires re-triangulation !!
- Better Grid quality !!
Motivation: Structured Grid

Structured Grid for Complex Geometries

- Sophisticated Multiblock and Overlapping Structured Grid Techniques are required for Complex Geometries

Overlapping grid system on space shuttle (Slotnick et al. 1994)
Motivation: Structured Grid

Structured Multigrid Techniques

- Multigrid techniques enable optimal $O(N)$ solution complexity.
- Based on sequence of coarse and fine meshes.
Motivation: Unstructured Grid

Unstructured Multigrid Techniques

Coarse level meshes constructed by agglomerating fine grid cells/equations.

An Agglomeration Multigrid Technique by Dimitri Mavriplis
Motivation: Quad-tree Decomposition

Properties
- Fast
- Adaptive
- Square Elements
- Line Solvers
- Nonconforming Nodes!!
- Complex Geometries!!
Motivation: Our Goals

Properties of an Optimal Grid Generation Technique

- Fast Algorithm
- High Quality Elements
- Complex Geometries
- Adaptive
- Multigrid Methods
- Line Solvers
- Conforming Elements
- Simple Optimization Step (for 3D)
- Parallelizable
Initial Background Grid
Spatial Decomposition

(a) Initial Background Grid

(b) Buffer Zone

(c) Spatial Decomposition

(d) New Nodes

(e) Old Nodes
Spatial Decomposition: Results For NACA0012
Buffer Zone Creation: Results For NACA0012
Buffer Zone Filling: Orthogonal Projection
Smooth Parts of the Boundary
Buffer Zone Filling: Orthogonal Projection

Singular Boundary Points
Buffer Zone Filling: Results For NACA0012
Buffer Zone Optimized: Results For NACA0012
Three Element Airfoil: Initial Mesh 256 points
Three Element Airfoil: Initial Mesh "Zoom In"
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Three Element Airfoil: Final Mesh 10,000 points
Three Element Airfoil: Zoom 1/8
Three Element Airfoil: Zoom 2/8
Three Element Airfoil: Zoom 3/8
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Three Element Airfoil: Zoom 5/8
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Three Element Airfoil: Zoom 7/8
Three Element Airfoil: Zoom 8/8
Unsteady Flow over a NACA0012 Airfoil
Re=800, \( \alpha = 20^\circ \)

Run Movie 1
Unsteady Flow over a NACA0012 Airfoil
Re=800, $\alpha = 20^\circ$

Run Movie 2
Unsteady Flow over 2 Vertical Cylinders
Re=200

Run Movie 3
Unsteady Flow over 2 Vertical Cylinders: Multigrid Levels
Unsteady Flow over 2 Vertical Cylinders: Multigrid Levels
Turbulent Flow Over a Flat plate \( \text{Re}=10^5 \)

Grid

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<td>12968</td>
<td>12995</td>
<td>99.568%</td>
<td>(2^{-1})</td>
<td>(2^{-14})</td>
<td>45°</td>
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</table>
Turbulent Flow Over a Flat plate $Re=10^5$

**Velocity Profile**

![Graph showing velocity profile with logarithmic scale](image)

- **Viscous Sublayer**
- **Logarithmic Law**
- **Computed**

**Results**
- 3-part Airfoil
- NACA Airfoil
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**Spatial Decomposition Buffer Zone**

**Fast Adaptive Hybrid Mesh Generation**

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Turbulent Flow Over a Flat plate $Re = 10^5$

Shear Stress

![Graph showing shear stress vs. x for turbulent skin friction and computed skin friction.](image-url)
Geometry Adaptation based on Curvature

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Recent Development
Treatment of Sharp Corners

Motivation

Our Technique

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Recent Development
Treatment of Sharp Corners
Thank you!