3D EULER SOLUTIONS USING AUTOMATED CARTESIAN GRID GENERATION

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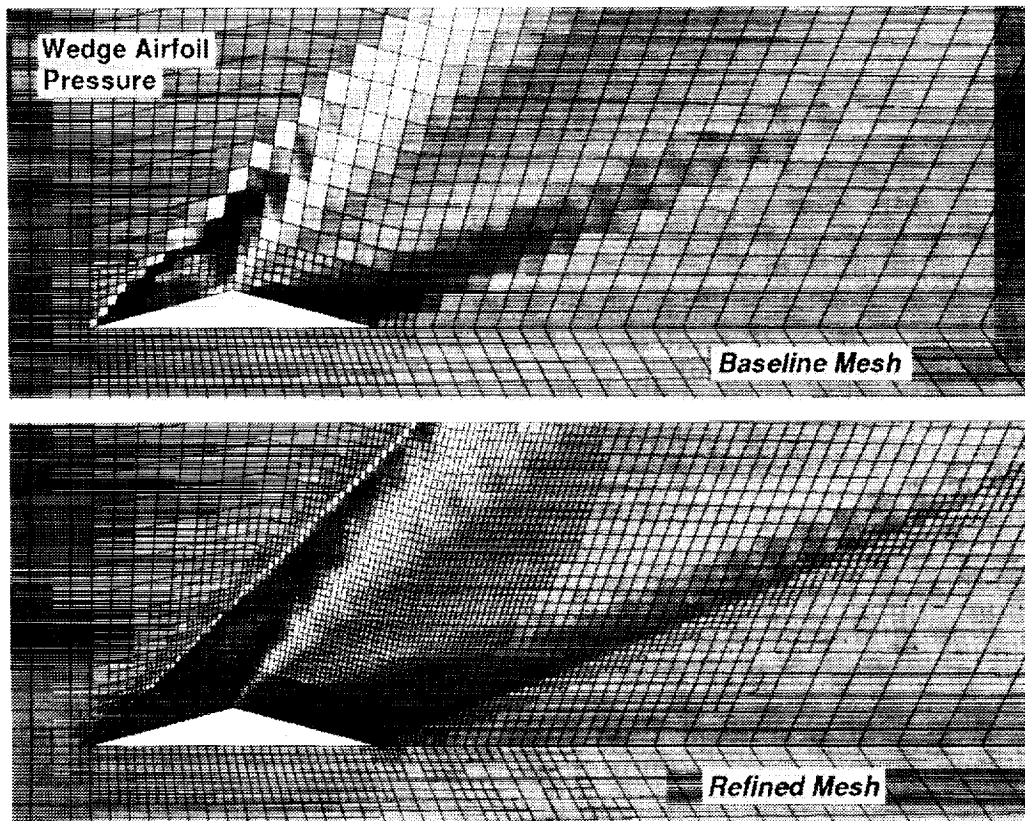
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Agenda

- History

- Cartesian Overview

- Technique Comparisons

- 3D Cartesian Grid Generation Strategy

- Survey of simple test cases

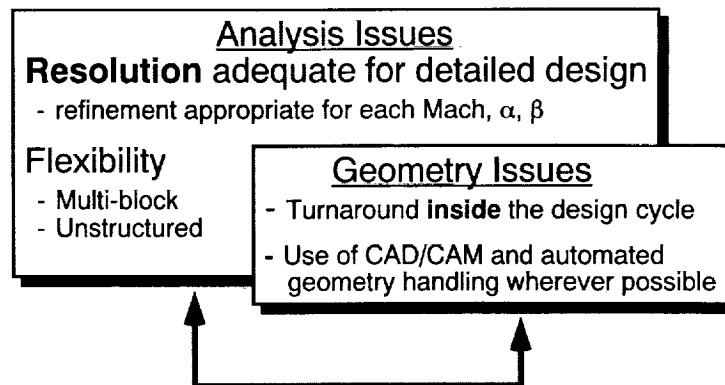- Current research and future plans

- Summary

History

- Lessons from ATP grid generation

- AIAA 91-0637 with Thomas and Cappuccio
  - Unstructured, refined, hexahedral body-fitted grid
  - Euler FV RK4 Jameson flow solver algorithm (FLO57)

- TIGER = Topologically Independent, Euler Refinement

- GIRAFFE = Grid Interactive Refinement and
            Flow Field Examination

Wedge Airfoil Pressure — *Baseline Mesh*

Refined Mesh

CFD and the Design Cycle

Compute *better* solutions *faster* and *cheaper*

Analysis Issues
Resolution adequate for detailed design
- refinement appropriate for each Mach, α, β

Flexibility
- Multi-block
- Unstructured

Geometry Issues
- Turnaround **inside** the design cycle
- Use of CAD/CAM and automated geometry handling wherever possible

Three Important Questions

Are CFDers doomed to eternal grid generation?

Why shouldn't CFD be like structural FEA?

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How can we automate the geometry manipulation and grid generation processes?

Cartesian Grid Strategy

- South, Clarke, Salas, Hassan, Berger, LeVeque, Powell, Epstein, Morinishi, TRANAIR

- Make the computer do the work
  - *Interactivity ≠ Automation*
  - Divorce surface grid from field grid
  - Use computational geometry algorithms to extract surface/cell intersection information
  - Use NURBs (Non-Uniform Rational B-Splines) to maintain a single, accurate, database

- Use grid refinement for "efficient" resolution
  - Unstructured grid (block or cell)
  - Flowfield and geometry-based refinement

Technique Comparisons

Task	Structured Body-fitted	Cartesian
Grid generation	tedious and boring time-consuming requires surface grid good tools are available	automated NURB accuracy no surface grid research software
Flux and BCs	"simple" and familiar	"complicated"
Connectivity overhead	minimal	~60 words/cell
Grid refinement/ adaptation	not automated difficult	automated for both geometry and flowfield
Flow solver	highly vectorizable	vectorizable

TIGER Surface Geometry

Entity	Advantages	Disadvantages
Triangles	"Simple" intersections LaWGS / FEM / PANAIR Compute - inexpensive	Poor refinement accuracy Creation Loss of surface information

NURBS	Direct from CAD
	Complete accuracy
	Complete information
	NASA/IGES standard
		"Nonlinear" intersections
		  - tolerance specifications
		  - polynomial root-finding
		Topology determination
		Unfamiliarity
		Compute - expensive

2-Step Cartesian Grid Generation Algorithm

1 - Create initial equi-spaced Cartesian grid

- Flag cells that intersect with surface
- Refine along with a number of neighbors
- Repeat to create desired resolution

2 - Compute cell geometric information

- face areas
- body surface normals
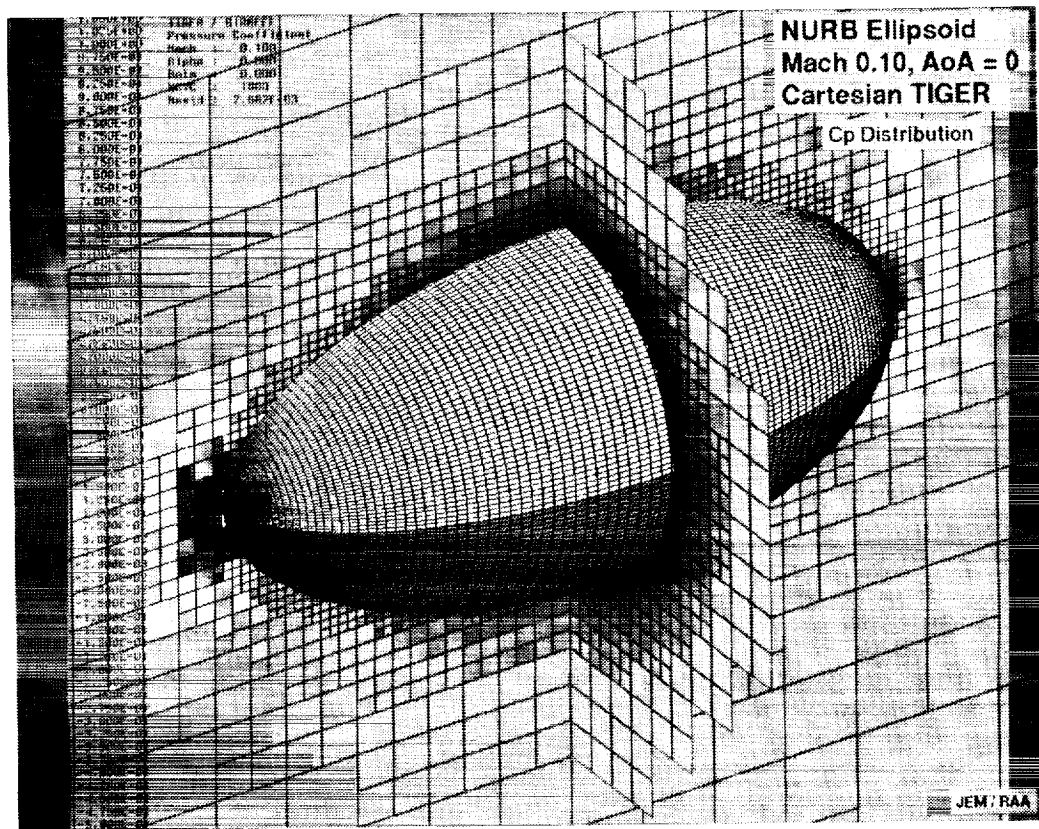- cell volumes
- face and volume centroids

Current TIGER Connectivity Data Structure
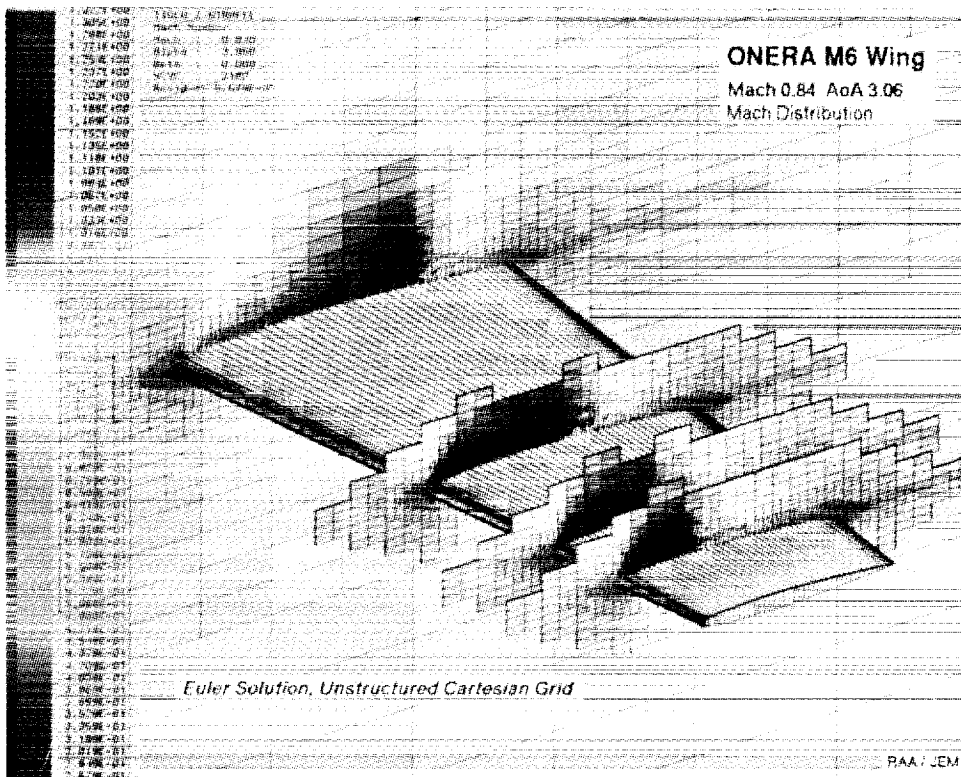
Item	Words per cell
Pointer to connecting cells	6 faces x 4 connections per face
Face BC flags	6 faces x 2 flags per face
Face area vectors	7 faces x 3 components per face
Cell Refinement Level	1
Cell BC flag	1
Cell volumes	1

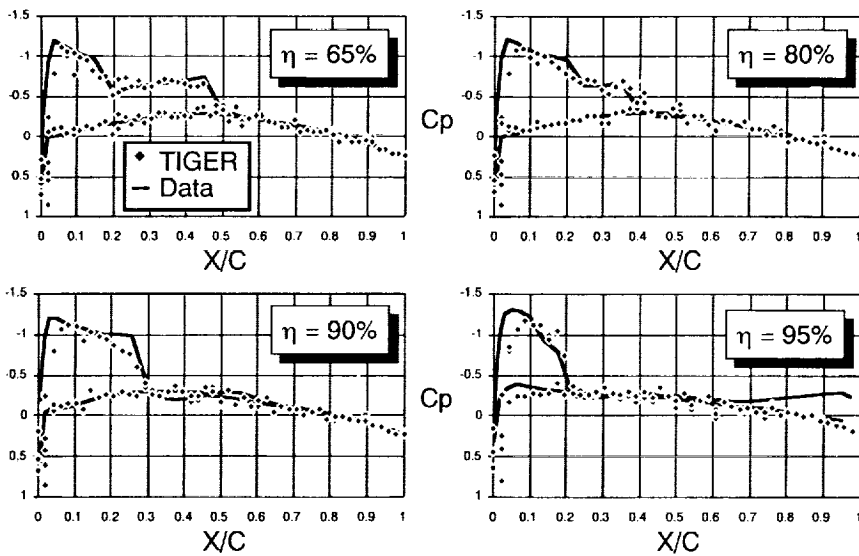Unstructured Cartesian Overhead ~ 60+ words per cell

Survey of Test Cases

- Prolate Spheroid - NURB input

- ONERA M6 wing - Triangle input

- HSCT with LE flap - Triangle input

ONERA M6 Wing
Mach 0.84 AoA 3.06
Mach Distribution

Euler Solution, Unstructured Cartesian Grid

ONERA M6 Mach=0.84 α=3.06

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TIGER Euler Solution
Unstructured Cartesian Grid

HSCT Grid Generation Command Files

Step 1

```
1            1: use tiger.net data   2: use tiger.tri
1            1: flip y-z  0: don't flip
1            1: make new base grid  2: restart
-1   4000        : x-range
-1300   1700     : y-range
0   1201         : z-range
17  15  9        : dims
1            1: split surface cells  0: stop
6                : number of splitting passes
2                : number of buffer layers
1            1: reset symmetry plane cells  0: skip
1            1: compress the files  0: skip
```

Step 2

```
1     1: read from tiger.net  2: tiger.tri
1     1: flip y-z  0: don't flip
1     1: reset symmetry plane cells  0: skip
1     1: compress files  0: skip
```

Current Research and Future Plans

- Improved flux and dissipation modeling

- Improved boundary conditions

- "Intelligent" grid generation

- Flowfield refinements

- Validations

Summary

- Use of a single NURB geometry database for design and analysis has many advantages

  - allows for geometry manipulation with commercial CAD/CAM tools
  - provides analyst with <u>complete</u> and <u>accurate</u> surface information
  - provides consistent method for data transfer

- A mature unstructured Cartesian approach will have additional advantages

  - eliminate surface and volume gridding tasks via automation
  - provide local resolution appropriate for each flow condition
  - shrink CFD turnaround from months to hours
  - allow designers to concentrate on aerodynamic performance instead of computational geometry and numerical analysis

- Interactive techniques should be viewed as short term solutions, and not as long term CFD goals

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