2D & 3D HYPERSONIC FLOWS WITH UNSTRUCTURED MESHES

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OUTLINE

Introduction

2D Viscous Shock-Shock Interaction

3D Inviscid NASP-Like (Unadapted)

3D Inviscid NASP-Like (Adapted)

INTRODUCTION

Funded by Aerothermal Loads Branch (NASA LaRC)

Development of finite elements in fluids and unstructured grid generation (began 1983-1984)

In-house research
  Civil servants and contractors

Grantees’ research
  Morgan, Lohner, Peraire (Swansea)
  Hughes (Stanford)
  Oden (Austin)
  Thornton (ODU)

Current status
COUPLED MODULES

MESH GENERATOR  SOLVER

ERROR INDICATOR

MESH GENERATION

Advancing Front Method

Generation Parameters
- Spacing
- Orientation
- Stretching

Sources
- Point
- Line
- Triangles

Background Mesh
2D CAPABILITIES
(LARCNESS)

Generation of initial meshes
Structured near walls
Unstructured elsewhere

Generation of adapted meshes
(Remeshing) from previous solution

Mesh refinement
Solution adaptive
Geometry-based

Mesh movement

2D SHOCK-SHOCK INTERACTION
Schematic
INITIAL MESH

Mesh

29,499 elements

U-Velocity Contours

ADAPTED MESH

Mesh

80,725 elements

U-Velocity Contours
MESH REFINEMENT
Meshes

Original
49,048 elements

Refined
80,725 elements

MESH REFINEMENT
U-Velocity Contours

Original

Refined
3D CAPABILITIES
(FELISA)

Developed by Peraire, Morgan, Peiro

3D Unstructured Mesh Generator

Solver
  Hypersonic Flows
  Unstructured Multigrid
  Matrix Dissipation

Adaption
  Remeshing
  Refinement

SUMMARY OF MESHES GENERATED BY VARYING SOURCE STRENGTHS

<table>
<thead>
<tr>
<th>MESH</th>
<th>SURFACE TRIANGLES</th>
<th>VOLUME TETRAHEDRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6,348</td>
<td>39,004</td>
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<tr>
<td>2</td>
<td>24,402</td>
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<td>3</td>
<td>76,254</td>
<td>1,303,666</td>
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MESH 2

CLOSE-UP OF MESH 2
MACH NUMBER CONTOURS
Mesh 3

VEHICLE BOTTOM SURFACE
Mesh 3

Mesh

Density Contours
## SUMMARY OF ADAPTED MESHES

<table>
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<th>MESH</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41,736</td>
<td>531,610</td>
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<tr>
<td>2</td>
<td>73,930</td>
<td>1,469,105</td>
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### ADAPTED MESH 1

![Adapted Mesh 1 Diagram]
CLOSE-UP OF ADAPTED MESH 1

MACH NUMBER CONTOURS
Adapted Mesh 1
VEHICLE BOTTOM SURFACE
Adapted Mesh 1

Mesh

Density Contours

ADAPTED MESH 2
CLOSE-UP OF ADAPTED MESH 2

VEHICLE BOTTOM SURFACE
  Adapted Mesh 2

Density
Contours
CONCLUSIONS

Adaptive remeshing demonstrated for problems with large number of elements.

Though efficient, these schemes exhaust cpu-time, memory and disk-space on current computers.

3D meshes with element sizes equivalent to those necessary in 2D would need more than 10 million elements.

Current capability is significantly better than what was available only a few years ago.

Further improvements in mesh generation, flow solvers and adaptivity still needed.