Mesh adaptation for Large Eddy Simulation for compressible combustion

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Applications

- Prediction of combustion in highly complex cases
Combustion in Rockets vs. Gas Turbines
Combustor/Turbine design?

Factor Project
Duchaine et al
The BKD Simulation

Temperature iso-surface coloured by axial velocity

Schmitt et al
Numerical approach

Courtesy of CTR Stanford

DNS

LES

RANS

Feed back
The AVBP code can handle standard multi-element unstructured meshes.

The explicit cell-vertex approach allows for relatively low quality meshes.

- Only constraints are:
  - "good" cell to cell aspect ratio
  - Highest minimum volume possible (Explicit scheme)

Current workflow involves mainly Centaur soft meshing software but is compatible with all standard meshing tools (gmsh, icemcfd, gridgen, etc..)
How did we stumble upon adaptative meshing?

- Mario Falese Phd: LOTAR experiment
  - Very different results with similar models …

<table>
<thead>
<tr>
<th>CODE</th>
<th>SGS MODEL</th>
<th>VELOCITY MAGNITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVBP (CERFACS, IFP)</td>
<td>SIGMA (Nicoud et al. 2011)</td>
<td><img src="Straight" alt="OPEN" /></td>
</tr>
<tr>
<td>YALES2 (CORIA)</td>
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<td>DYN. SMAG. (Germano et al. 1991)</td>
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How did we stumble upon adaptative meshing?

- Mario Falese Phd: LOTAR experiment
  - Very different results with similar models …
  - Resolved with **Targeted Manual mesh refinement**
How did we stumble upon adaptive meshing?

- Mario Falese Phd: LOTAR experiment
  - Developed a first adaptation framework based on MMG 4

![Original mesh](image1.png)
![Adapted mesh (y+)](image2.png)
Mesh refinement method @cerfacs today

- Uses the **MMG libraries** (Dobrzynski et al) v5.X
  - Integrated into our open source **mesh management tool HIP** (Mueller et al, Queen Mary University)
    - Handles mesh manipulation
      - rotation/translation/scale/etc
    - Data interpolation from one grid to another
    - Data conversion
      - (fluent, cgns, avbp, n3s, gmsh, ensight)
    - Element conversion
      - 2D ==> 3D
      - Quad -> Tri
      - Etc …
Use case: Flame holder

- Adaptation using Grad C/C
How does it work?

- Complete abstraction of the metric for HIP.
  - User provides a scalar field which correspond to the requested deformation.
Example: Metric for pressure losses

- **LIKE**: Loss in Kinetic Energy metric.
  - Based on the average total dissipation rate

\[
\Phi = (\mu + \mu_t) \left( \frac{\partial \tilde{u}_i}{\partial x_j} + \frac{\partial \tilde{u}_j}{\partial x_i} \right)
\]

Application to pressure losses

Original mesh colored by LIKE

Adapted mesh
Application to pressure losses

- Convergence of the method
- Best user refinement leads to 12% error

Daviller et al
Dynamic flows

Esnault et al

MMG and mesh coarsening

- Using MMGS lib to created a coarsened outline for:
  - Simple visualisation
  - GUI case setup

![Diagram showing mesh coarsening process]

Paraview statistics

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</table>

MMGSLIB: ELAPSED TIME 1.25s
Current work …

- Handeling hybrid meshes
- Periodicities (work in progress)
- Parallelisation (ParMMG ?)
- Automation
Automation

- Large Eddy Simulation is now a good tool
- But **highly dependent on the user**
  - Mesh adaptation removes some of the expert bottlenecks
  - But initial mesh still need to be high quality
    - Usual cases: 1 to 10 days of meshing for the initial guess
    - On piston engine cases, 1 to 3 months of meshing for a single simulation (phase deformation)
Automatic simulation for piston engines

- Automatic remeshing using MMG (metric: deformation)

Q. Male et al. Challenge IRENE Renault/CERFACS
Grand Challenge GENCI/TGCC on IRENE

- Pre-chamber ignition:

Q. Male et al. Challenge Renault/CERFACS
No mesh method

- Semi-automatic mesh method for LES
  - Generate an initial mesh using GMSH
  - Use HIP/MMG to improve quality
  - Perform simulation, adapt (here grad rho/rho )
  - Loop previous step until convergence.

Current issues:
- Hysteresis ?

220k

53M
No mesh method

- Semi-automatic mesh method for LES

Automatic mesh

Quality improvement with MMG