FSI*ce
A Modular Simulation Environment for Fluid-Structure Interactions

Miriam Mehl
Department of Computer Science, TU München
Outline

- concept of FSI*ce
- data transfer for non-matching grids
  - octree
  - neighborhood search
- coupling control
  - multigrid
  - further potential
Plug-and-Play for FSI

MpCCI

Fluid Solver

Structure Solver

data mapping

coupling strategy
Plug-and-Play for FSI

Fluid Solver

MpCCI

Structure Solver
Plug-and-Play for FSI

Coupling Strategy
Central Surface Mesh

Fluid Solver

Structure Solver

FSI*ce
Data Mapping

• any types of solver grids

• tools:
  • neighbourhood search
  • interpolation/projection
Data Mapping

- central mesh
- octree
- grid point
- triangle + projection
Data Mapping – Octree Generation

<table>
<thead>
<tr>
<th>octree depth</th>
<th>time (sec)</th>
<th>nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.8</td>
<td>203,905</td>
</tr>
<tr>
<td>9</td>
<td>4.9</td>
<td>3,288,225</td>
</tr>
<tr>
<td>11</td>
<td>48.2</td>
<td>52,662,337</td>
</tr>
<tr>
<td>13</td>
<td>662.8</td>
<td>842,687,105</td>
</tr>
</tbody>
</table>

octree generation measured on a Pentium 4 2.4 GHz processor with 512 kB cache
Data Mapping – Neighbourhood Search

<table>
<thead>
<tr>
<th>Cart.res.</th>
<th># triang.</th>
<th>runtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>256</td>
<td>8,000</td>
<td>2.6 sec</td>
</tr>
<tr>
<td>512</td>
<td>8,000</td>
<td>10.1 sec</td>
</tr>
<tr>
<td>512</td>
<td>32,000</td>
<td>14.3 sec</td>
</tr>
<tr>
<td>512</td>
<td>128,000</td>
<td>17.4 sec</td>
</tr>
</tbody>
</table>

neighbourhood search measured on a Pentium M 1.6 GHz processor with 2048 kB cache
Coupling Control

- explicit/implicit
- subcycling
- next: multigrid
Coupling Control – Multigrid

- solve fluid
- exchange data
- solve structure
- exchange data
- compute residual
- restrict residual
- solve coarse
Coupling Control – Multigrid

<table>
<thead>
<tr>
<th>FSI*ce</th>
<th>Solver</th>
</tr>
</thead>
<tbody>
<tr>
<td>multigrid cycles</td>
<td>multigrid functionality</td>
</tr>
<tr>
<td>restrict central mesh</td>
<td>extended data mapping</td>
</tr>
</tbody>
</table>

➤ setup-phase for central mesh hierarchy
Coupling Control – Multigrid

benefits of multigrid:
• Bijl, van Zuijlen, Boscher, ECCOMAS CFD 2006:

   eff. gain: factor 10

1D linear piston problem
two-grid solver, coarsening in the fluid only
Central Mesh – Further Potential

- third numerical component: the wet surface
  - **LLM transient method** (Park, Felippa, Ohayon, 2001, Ross, 2006)

Source: Mike R. Ross, PhD thesis, 2006
Central Mesh – Further Potential

\[ \psi_1^2 = F_{\mathcal{P}}(g_{\mathcal{F}}^1 - D^T B_{\mathcal{F}} \lambda_{\mathcal{F}}^1) \quad \psi_2^2 = F_{\mathcal{P}}(g_{\mathcal{F}}^2 - D^T B_{\mathcal{F}} \lambda_{\mathcal{F}}^2) \]

stable
parallel

Source: Mike R. Ross, PhD thesis, 2006
Central Mesh – Further Potential

Figure 5.7: Model with non-matching meshes.

Source: Mike R. Ross, PhD thesis, 2006
Central Mesh – Further Potential

reduced order models
- implicit coupling
- black box solvers
- high efficiency

Vierendeels,
Conclusion

- flexibility
  - solvers, coupling strategy
- enhanced coupling strategies
  - multigrid
- interface equation
- reduced order models