A 3D Multi-Block Mesh Interface Treatment For Finite Volume Fluid Flows Computations

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Multi-block meshes

Use of Multi-block meshes for finite volume methods

- Generate meshes more easily
- Use of independent dynamic meshes
Multi-block meshes

Use of Multi-block meshes for finite volume methods

- Generate meshes more easily
- Use of independent dynamic meshes

- Treatment of 3D unstructured meshes interface
Cell Centered Finite Volume Method

- Integration of advective and viscous fluxes on faces

\[
\text{Rhs} = \sum_i \int \int_{\Delta_i/\square_i} \left[ \tilde{f}_n^a (\tilde{w}_L, \tilde{w}_R, \tilde{v}_n^g) + f_n^d (\tilde{w}, \nabla \tilde{w}) \right] dS_i
\]

\[
\tilde{w}_{L/R} = w_{L/R} + (x - x_{L/R})^T \nabla (w)_{L/R} + ...
\]

⇒ FVM allows the use of non conformal meshes
Algorithm description

Two mesh blocks example - Boundary must be detected

- The interface is composed of two boundary meshes (mesh A and mesh B)
- Mesh A and mesh B faces have only one left neighbour node
- A new mesh C must be created with faces having one left and one right neighbour nodes
Three steps

- Locate mesh B vertices in mesh A faces or on boundary.
- Compute mesh B edges and mesh A edges intersection, cut all edges and create new mesh C.
- Build macro-faces having one left and one right neighbour node. Cut macro-faces.
Some Easy Problems

Is one vertex is in a given triangle?

Knowing \( x \), find \((\xi, \eta)\) parameters by solving

\[
x (\xi, \eta) = x_1 + \xi (x_2 - x_1) + \eta (x_3 - x_1)
\]

if \( \xi > 0 \) and \( \eta > 0 \) and \( 1 - \xi - \eta < 0 \), vertex is in triangle.
Some Easy Problems

Is one vertex is in a given quadrangle?

Knowing \( x \), find \((\xi, \eta)\) parameters by solving

\[
x(\xi, \eta) = \frac{1}{4} (1 - \eta) (1 - \xi) x_1 + \frac{1}{4} (1 - \eta) (1 + \xi) x_2 + \frac{1}{4} (1 + \eta) (1 + \xi) x_3 + \frac{1}{4} (1 + \eta) (1 - \xi) x_4
\]

if \(-1 < \xi < 1\) and \(-1 < \eta < 1\), vertex is in quadrangle.
Some Easy Problems

Do two edges intersect each other?

Find \((\xi, \eta)\) parameters such as

\[
\frac{1}{2} (1 - \xi) \ x_1 + \frac{1}{2} (1 + \xi) \ x_2 = \frac{1}{2} (1 - \eta) \ y_1 + \frac{1}{2} (1 + \eta) \ y_2
\]

if \(-1 < \xi < 1\) and \(-1 < \eta < 1\), the intersection exists.
Interface treatment algorithm

Locate mesh B vertices in mesh A faces
Interface treatment algorithm

Locate mesh B vertices in mesh A faces

Find nearest boundary edge or vertex
Interface treatment algorithm

Locate mesh B vertices in mesh A faces

Find nearest surrounding edge or vertex
Repeat operation
Interface treatment algorithm

Locate mesh B vertices in mesh A faces

Find nearest surrounding edge or vertex
Repeat operation
Interface treatment algorithm

Locate mesh B vertices in mesh A faces

Check if the vertex is in one of the surrounding faces
Interface treatment algorithm

Cut edges and build new mesh C

Find intersections, cut edges and create new vertices for new mesh C.
Interface treatment algorithm

Cut edges and build new mesh C

Find intersections, cut edges and create new vertices for new mesh C.
Interface treatment algorithm

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Interface treatment algorithm

Cut edges and build new mesh C

Find intersections, cut edges and create new vertices for new mesh C.
Interface treatment algorithm

Find intersections, cut edges and create new vertices for new mesh C.
Interface treatment algorithm

Cut edges and build new mesh C

Store for each new edge the identification number of neighbour nodes
Interface treatment algorithm

Cut edges and build new mesh C

Store for each new edge the identification number of neighbour nodes
Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes.

Create macro face with edges having the same nodes in mesh A and B.
Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes

Mesh A node numbers
Mesh B node numbers

Create macro face with edges having the same nodes in mesh A and B.
Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes

Create macro face with edges having the same nodes in mesh A and B.
Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes.

Create macro face with edges having the same nodes in mesh A and B.
Build macro faces having one left and one right neighbour nodes

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Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes

Mesh A node numbers
Mesh B node numbers

Create macro face with edges having the same nodes in mesh A and B.
Interface treatment algorithm

Build macro faces having one left and one right neighbour nodes

Mesh A node numbers
Mesh B node numbers

Create macro face with edges having the same nodes in mesh A and B.
Cut macro faces into triangles or quadrangles
Duct flow

Two mesh blocks - Boundary must be detected
Duct flow

One left mesh
Duct flow

One right mesh
Duct flow

Interface to be computed and boundary to be detected
Duct flow

Result
Duct flow

One left mesh
Duct flow

One right mesh
Duct flow

Interface to be computed and boundary to be detected
Duct flow

Result
Duct flow

Macro face treatment

Macro Face
Duct flow
Duct flow
Flow past a sphere

Three mesh blocks
Flow past a sphere

Two left meshes
Flow past a sphere

One right mesh
Flow past a sphere

Interface to be computed
Flow past a sphere

Result

[Image of a flow simulation past a sphere]
Flow past a sphere

Two left meshes
Flow past a sphere

One right mesh
Flow past a sphere

Interface to be computed
Flow past a sphere

Result
Flow past a sphere
Flow past a sphere
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
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Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Unsteady flow with moving boundary
Conclusion

- An algorithm for the treatment of the interface between 3D unstructured meshes has been developed
- Independent multi-block meshes can be used to simulate fluids flows with moving boundaries
- Parallel implementation is not done. An interface must be on one single processor
- Possibility to treat the interface between solid and fluid meshes in fluid structure interaction problems