Project JARA SIM

Towards a Computational Model of Blood Flow in the Left Human Heart, Aorta and Connecting Vessels

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Numerical simulations

Step 1: Blood flow simulation in aorta and connecting vessels (rigid mesh)

Step 2: Blood flow simulation in a deforming mesh

Step 3: Simulation of left ventricle
(30 deforming meshes for 1 heart cycle)

Step 4: Left ventricle and connecting vessels

- Step 1 100% complete
- Step 2 60% complete
- Step 3 20% complete
- Step 4 not in this funding period
Aorta simulation:

Step 1: blood flow was computed for 5.014 l/min and 15.105 l/min case

good general agreement with data from literature

Fig1: velocity profile for flow rate 5.014 l/min computed by CATS

Fig2: CFD results for pulsatile blood flow in an idealized aorta according to Shacheraghi [1]

Fig3: Left: velocity profile in curved pipe [2]  
Right: velocity profile in a bifurcation [3]
Aorta simulation:

Step 1: blood flow was computed for 5.014 l/min and 15.105 l/min case

good agreement with PIV data from HIA

Fig4: velocity profile in different sections for flow rate 5.014 l/min computed by CATS

Fig5: velocity profile in different sections, comparison CFD with PIV
Step 2: Blood flow simulation for a deforming mesh starting from a given volume mesh, its surface mesh and the geometry for a new mesh (or several meshes) XNS updates the volume mesh node coordinates.

As a first simple test we looked at a coronary artery which starts to become occluded (stenosed vessel).

The mesh update technique was validated for this application, flow computations are ongoing. Thrombosis computation planned.

**Fig6:** 3D deformation of a tube in XNS. Inner node coordinates are updated in the process.

**Fig7:** Experimental data and CFD analysis using the shown setup was studied by Bark. Occlusion time = 800 seconds. [4]
Working with Left Ventricle Surface Mesh from Mimics:

Step 3: Simulation of left ventricle (30 - 60 deforming meshes for 1 heart cycle)

HIA managed to assure identical topology for all meshes

Surface mesh smoothening required

Fig8: Meshes for different time steps have same topology.

Fig9: Overlapping elements were a problem in the beginning.
Working with Left Ventricle Surface Mesh from Mimics:

Fig10: Left: original mesh; Right: mesh with improved surface element quality.

High quality surface meshes allow for better quality volume meshes. Sharp angles have to be avoided.
**XNS mesh update and flow simulation strategy:**

**Ablauf**

1. Geometrie aus MRT Daten abstrahlen
2. Surfacemesh erzeugen
3. Volumenmesh erzeugen
4. ShiftVecotor erzeugen
5. Berechnung des nachfolgenden Gitters mittels des ShiftVectors
6. Simulation der Herzströmung
7. Auswertung der Ergebnisse

**Interpolation**

<table>
<thead>
<tr>
<th>Gitternr.</th>
<th>Interpolation zwischen ( )^* und ( )</th>
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<tbody>
<tr>
<td>1 - 2^*</td>
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<td>2 - 3^*</td>
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<td>3 - 4^*</td>
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<td>4 - 4.5^*</td>
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<td>4.5 - 5^*</td>
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**Fig11:** Two subsequent mesh geometries. Major deformation during only one time step occurs. Maximum displacement per time step = 10mm
Outlook:
Step 1: Aorta simulation
• publish data
• joint publication HIA, CATS
• numerical simulation for pulsatile

Step 2: Deforming mesh simulation
• Gather further experience working with time dependent geometries with coronary artery model

Step 3: Left ventricle simulation
• receive all meshes from HIA (minimum 30, probably 60)
• perform mesh update and flow simulation
• decide on adequate boundary conditions
• method to account for heart valve movement
• joint publication HIA, CATS, HPC, JSC

Step 4: Left ventricle and connecting vessels
• will not be started within JARASIM; write proposal for further funding
Literature: