BIOFLUID MECHANICS

ON COMPUTATIONAL FLUID DYNAMICS

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Faculty of Architecture and Engineering
Ugent

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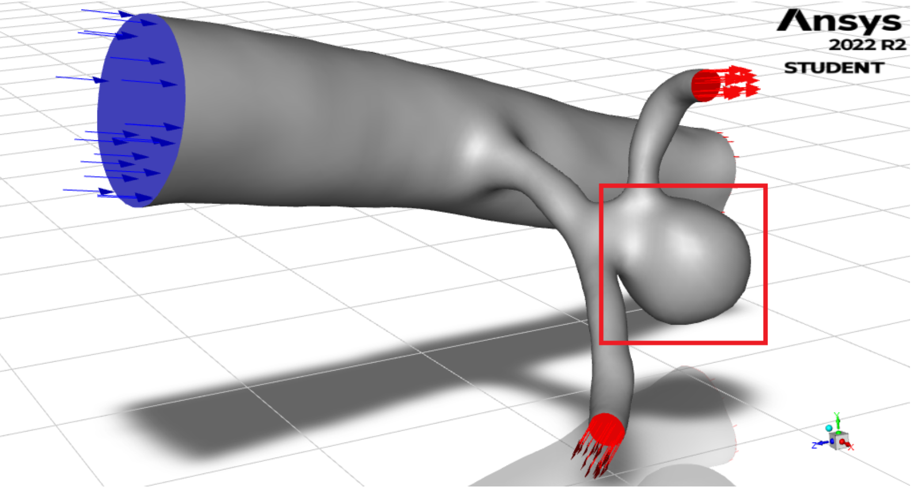
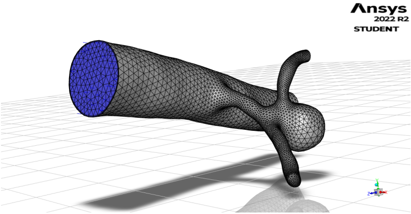
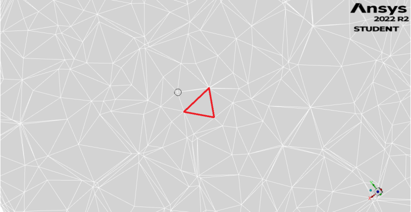
The Aneurysm

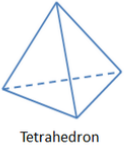


Mesh element types





$\rightarrow$ in bulk tetrahedral (4 faces)



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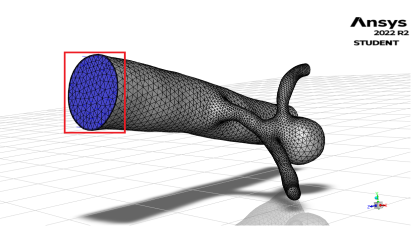
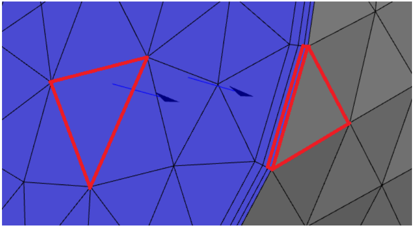
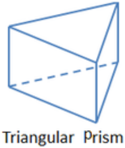


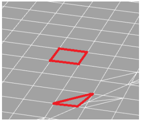
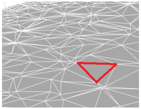
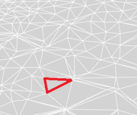


→ in bulk tetrahedral (4 faces)

→ at boundaries prism



Mesh comparison

file	Element Type	N	Bulk View
Mesh1.cas	hexahedral, prism	496718	
Mesh2.cas	tetrahedral, prism	80846	
Mesh3.cas	tetrahedral, prism	319342	
Mesh4.cas	tetrahedral, prism	486960	

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Blood modelling

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- → At large scales and relative high velocities, blood can be assumed to have a constant density (incompressible flow) and viscosity.
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$\rightarrow$ At small scales (around the size of a RBC) and relative slow velocities, blood can no longer be assumed homogeneous and it's apparent viscosity becomes very important.

$\Rightarrow$ This model is physiological.

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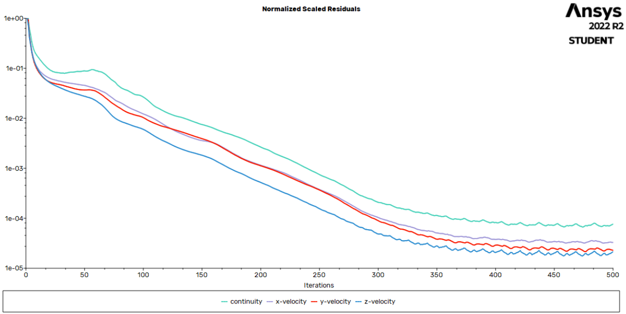
- The residuals OK!



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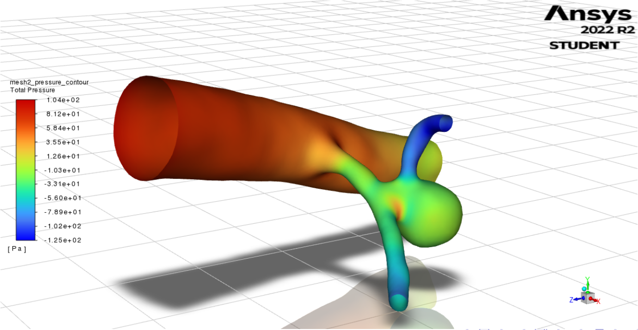

Results of initial simulation

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- Pressure contour: as expected, flow goes from higher pressures to lower pressures
- Conservation of mass?

Mass Flow Rate	[kg/s]
inlet.1.1	0.078264423
outlet-1.1.1	-0.0039132212
outlet-2.1.1	-0.0039132212
outlet-3.1.1	-0.070437981
Net	-1.3877788e-17

→ Net mass flow rate ≈ 0
⇒ mass is conserved!

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Mesh sensitivity

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Consider a quantity A calculated via computational fluid dynamics with a mesh size N. Let's say that A_1 is calculated with a mesh size N_1 and A_2 is calculated with a mesh size N_2, with $N_2 > N_1$. Then the mesh sensitivity, here denoted as ϵ, between A_1 and A_2 is defined as

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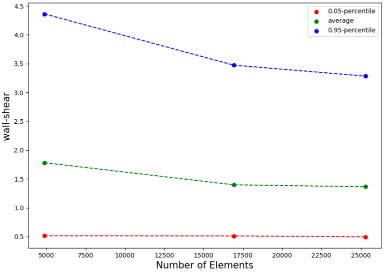
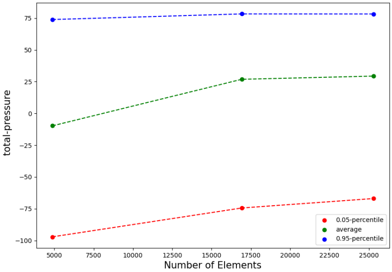
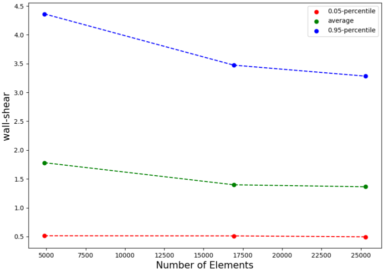
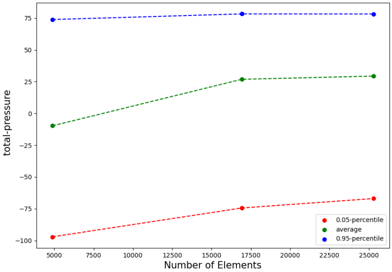
ϵ indicates how much accuracy the model gains if the mesh size would be increase by ΔN elements. If ϵ is very small and the computitional time relativly large then it would not be faivorable to increase the mesh size.

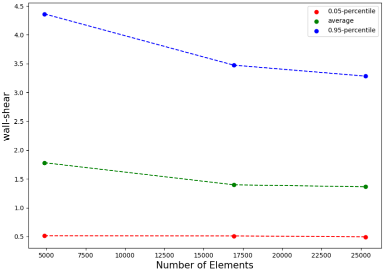

0.05-percentile
average
0.95-percentile
wall-shear
Number of Elements
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
5000
7500
10000
12500
15000
17500
20000
22500
25000

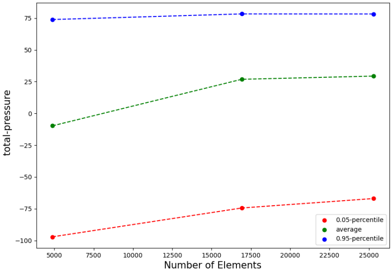

0.05-percentile
average
0.95-percentile
total-pressure
Number of Elements
75
50
25
0
−25
−50
−75
−100
5000
7500
10000
12500
15000
17500
20000
22500
25000





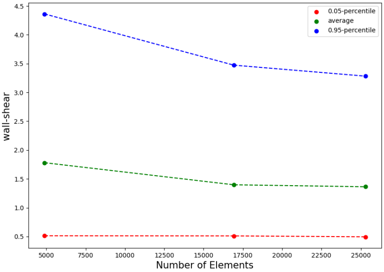
Observations:

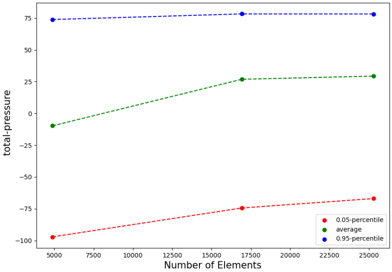




Observations:

$\rightarrow$ From Coarse to Medium: relative high improvement

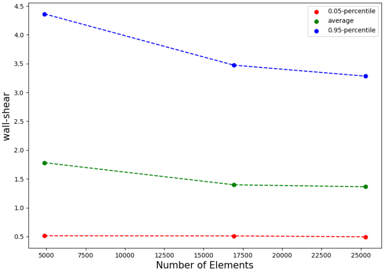


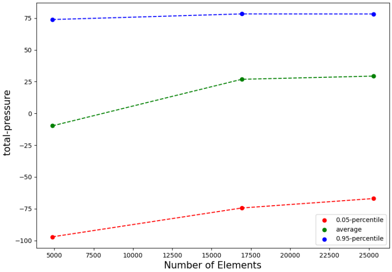


Observations:

→ From Coarse to Medium: relative high improvement

→ From Medium to Fine: relative low improvement





Observations:

$\rightarrow$ From Coarse to Medium: relative high improvement

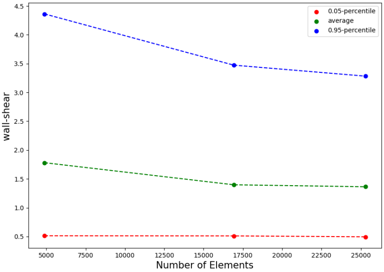
$\rightarrow$ From Medium to Fine: relative low improvement

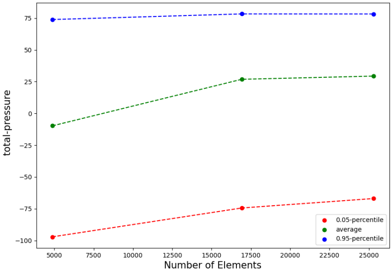
$\rightarrow$ Estimate computation time (all converged!):

Coarse: $T < 3$ min

Medium: 2 min $< T <$ 4 min

Fine: 5 min $< T$





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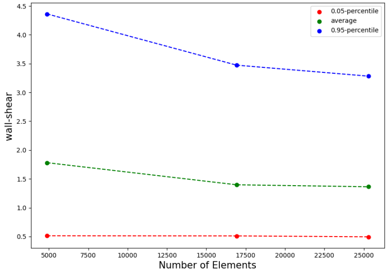

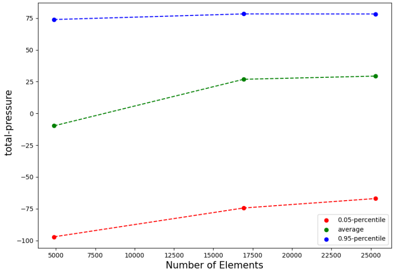

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⇒ Medium mesh will suffice

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- More advanced techniques for mesh sensitivity analysis?

$\rightarrow$ Numerical Mathematics Divergence Theory: knowing the structure of the CFD model at its properties

Me: If I'm patient, eventually ANSYS will solve. I'll just do something in the meantime

Inner Me: Loosen the convergence criteria and coarsen the mesh. It'll solve faster