Towards large number of red blood cell simulations with YALES2BIO

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Rheoblood project at IMAG

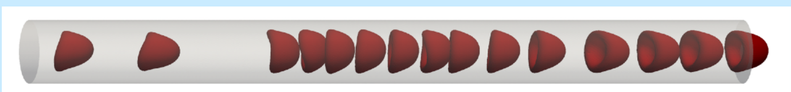
- The objective of the Rheoblood project is to decipher and characterize the behavior of blood.
- The main blood properties are determined by the behaviour of its main constituents: the red blood cells (RBCs).
- At IMAG, a dedicated solver is developed to simulate flows of red blood cells: **YALES2BIO**. This solver has been validated on several cases involving single red blood cells[1,2].
- To perform simulations of multi-red blood cell flows on super-computers such as **MUSE**, it is important to demonstrate that **YALES2BIO** is scalable.

Multi-red blood cell study

- Based on the work of Fedosov[3] and Pries[4], the flows of red blood cells in tubes are studied for three tube diameters, with a fixed hematocrit (15%).

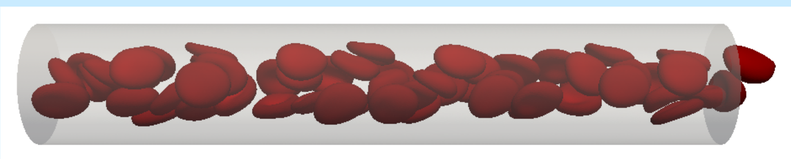
- **Configuration 1:**

Diameter = 10 µm
Number of RBC = 15



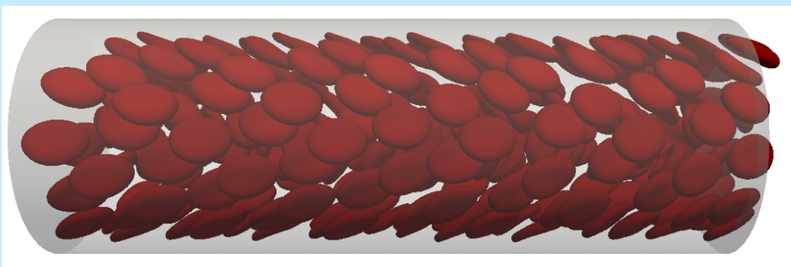
- **Configuration 2:**

Diameter = 20 µm
Number of RBC = 58



- **Configuration 3:**

Diameter = 40 µm
Number of RBC = 228



- This study is a work in progress.
- The main purpose of this study is to demonstrate that YALES2BIO can perform qualitative and efficient multi-red blood cell simulations.

YALES2BIO's scalability

- Measuring the **scalability** of a code indicates how **efficient** the software is when increasing the number of cores.
- For example, one can study the **strong scaling**: for a given problem, the number of cores is increased and one can plot the **speed up** response

- **Test case:** 40x40x140 µm channel, with a resolution of **0.25 µm**, in which **448 RBCs** are placed (c.f. figure 1).

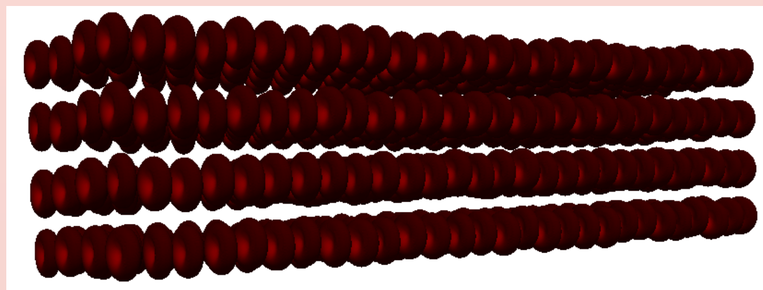


Figure 1: Snapshot of the test case used to measure the strong scaling

- **Result:** the strong-scaling performance is given by the **speed-up*** evolution in function of the number of processors. The figure 2 shows that YALES2BIO has a satisfactory scalability.

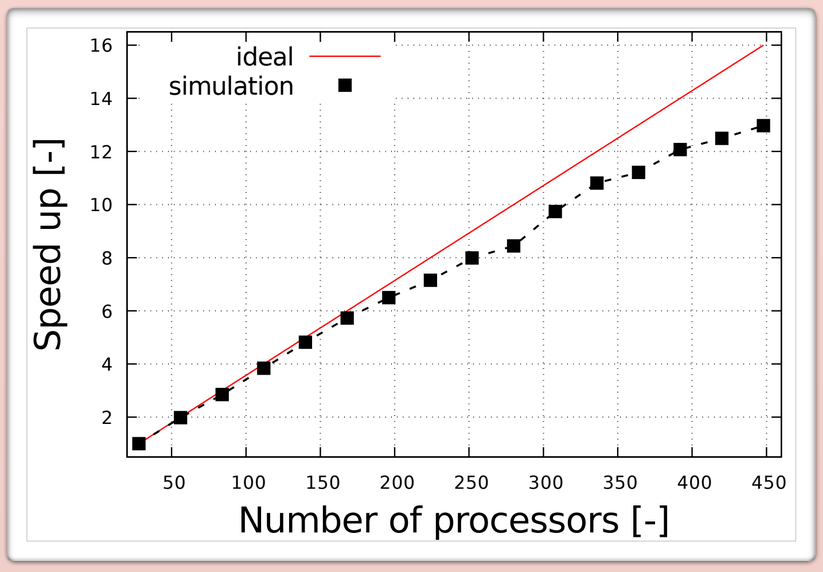


Figure 2: Strong scaling of YALES2BIO was done for a number of processors up to 448.

Perspectives

- It is planned to optimize the code in order to perform efficient simulations with more than 1,000 RBCs.
- To perform red blood cell flow simulations with larger hematocrits (30%, 50%), a **surface-surface detection algorithm** has to be implemented.

[1]: Mendez, S., Gibaud, E., & Nicoud, F. (2014). *Journal of Computational Physics*, *256*, 465-483.

[2]: Sigüenza, J., Mendez, S., Ambard, D., Dubois, F., Jourdan, F., Mozul, R., & Nicoud, F. (2016). *Journal of Computational Physics*, *322*, 723-746

[3]: Fedosov, D. A., Caswell, B., Popel, A. S., & Karniadakis, G. E. (2010). *Microcirculation*, *17*(8), 615-628.

[4]: Pries, A. R., Neuhaus, D., & Gaehtgens, P. (1992). *American Journal of Physiology-Heart and Circulatory Physiology*, *263*(6), H1770-H1778.