Master Thesis Experiment Report VI : Force Field Clot

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Abstract

Implementing a New Approach for the Clot

1 Context

The previous method of implementing a Clot as an inital step to simulate thrombolysis using the partial bounce-back method was unsuccesful. The accumulated density generated by Zou-He and the small amount of particle that passes through the clot made the method unviable. Instead, we will try a new force-based approach.

2 Description

The first thing we did was to make the system periodic: instead of having a inlet on the leftmost border and an outlet on the rightmost border, we made the system periodic on the west and east borders. The top and bottom border remain as node-based bounceback nodes as defined previously. Moreover, we removed the initial speed condition : before we started with a Poiseuille velocity curve on the leftmost border of the system to generate initial momentum and help the system converge faster. Now, instead of an initial velocity, we added a constant acceleration $F = [Fx, Fy]$ (constant in each direction) to the system. At each iteration, the velocity u increases with the given acceleration in each direction :

$$u^{(t+1)} = (u_x^{(t+1)}, u_y^{(t+1)}) = (u_x^t + Fx * t, u_y^t + Fy * t) \tag{1}$$

The clot will now be defined as a opposite force field that pushes the particles in the opposite direction to the flow. The opposite force of the clot will be defined as a value K. K is a mask of the same size as the lattice where each cell has the corresponding $[Kx, Ky]$ values defined locally. For bounceback nodes, $Kx = 1$, for the open path of the tube $Kx = 0$ and for the clot Kx is assigned a desired value. The outgoing PDFS of each site will now be pondered by the following equation:

$$fout = fout + FF \tag{2}$$

where $fout$ is the outgoing PDFs of each cell and FF the opposite force field defined for each direction i as:

$$FF_i = [\rho * (v_i^x * (Fx - Kx * u_x) + v_i^y * Fy)] * \frac{w_i}{cs^2} \tag{3}$$

where ρ is the density, v_i^x the velocity vector value in the x direction, v_i^y the velocity vector value in the y direction, w_i the weight of each direction i for the outgoing PDFs and cs^2 the speed of sound in lattice unites ($cs^2 = 1/3$). Note : the force field has been made here proportional to ρ as a choice.

3 Experiments

3.1 Experiment 1

3.1.1 Description

We first implemented the new method on a small 20x11 system. F is set as $F = [0.0001, 0]$ and K for the clot as $K[clot] = [0.001, 0]$. We set the viscosity as $\nu = 0.01$ and the initial density as $\rho = 2.5$. The system with clot placement is illustrated in Figure 1. The simulation runs for 11'000 iterations.

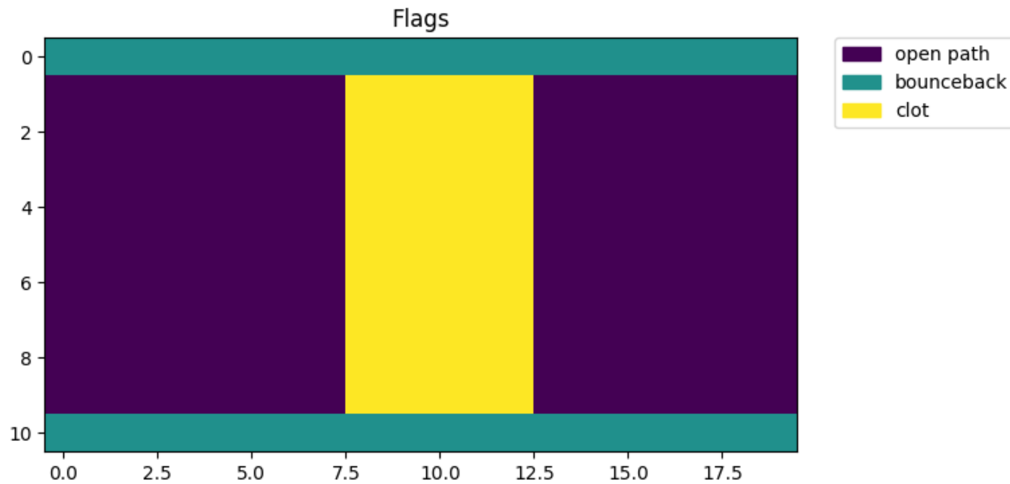

Figure 1: small system

3.1.2 Results

The results are shown in Figure 2. The first image is the norm of each local velocity. The second is the mean of each vertical slice of the velocity, the third is the mean of each vertical slice of the density, and the last is the flow (flow = density * velocity). We can observe the density decreasing inside the clot and the velocity behaved in the exact opposite way. This results in a constant flow (with a precision of 10^{-4}. The system behaves as expected, and we can now increase the dimensions.

3.2 Experiment 2

3.2.1 Description

We increase the size of the system and run it with the exact same parameters.

3.2.2 Results

Unfortunately the increase in dimensions induces a systematic numerical instability. Some digging is necessary.

4 Conclusion

5 References

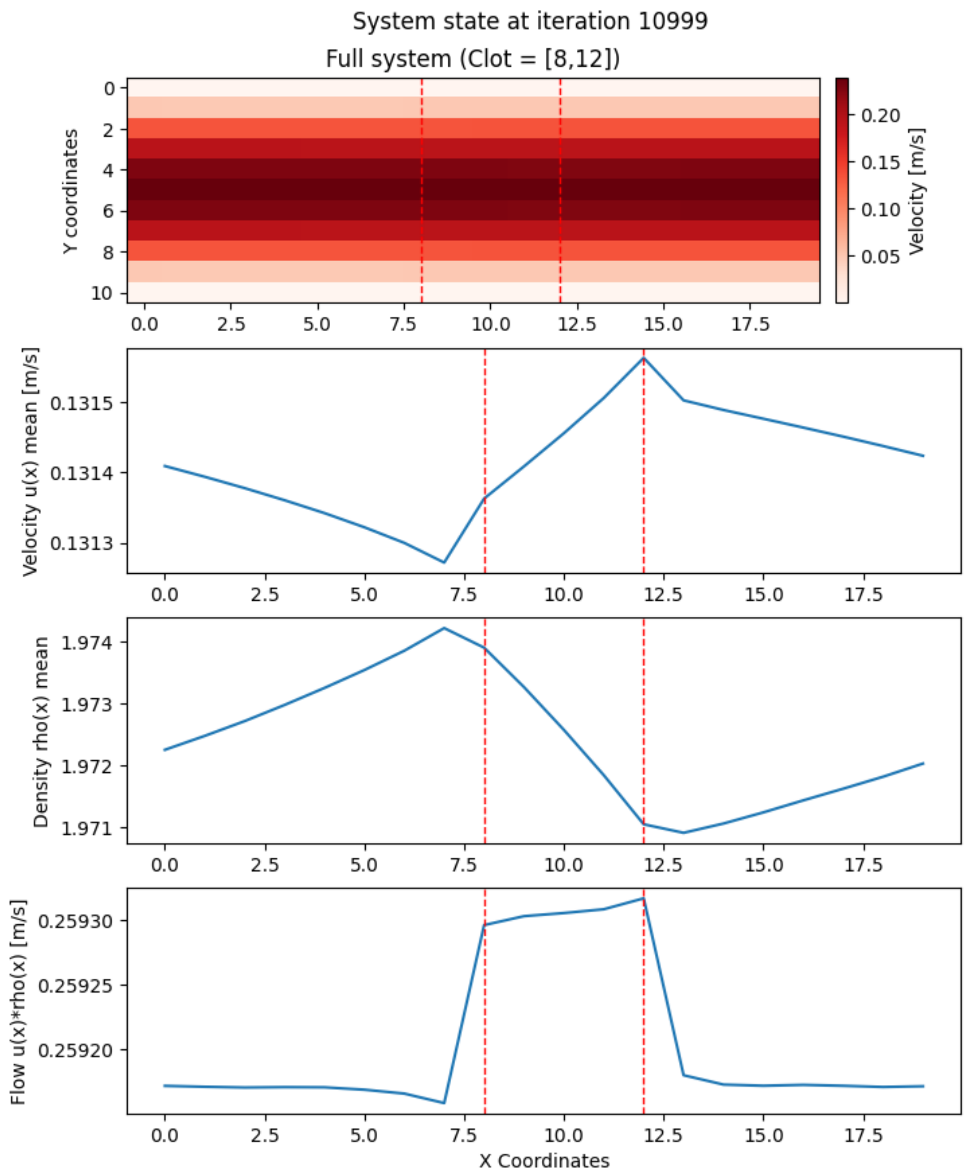

Figure 2: state at the last iteration