Massively parallelizable lattice Boltzmann method with regularized boundary conditions

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Lattice Boltzmann method

- Harvey is a massively parallel hemodynamics solver, based on the lattice Boltzmann method [1].
- Mesoscopic method that models fluid as particle distribution functions.
- Algorithm

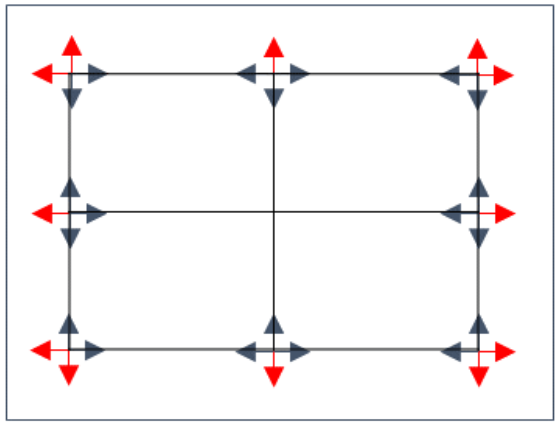
$$f_i(\mathbf{x} + \mathbf{c}_i\delta t, t + \delta t) - f_i(\mathbf{x}, t) = \Omega(f_i(\mathbf{x}, t) - f_i^{eq}(\mathbf{x}, t)$$

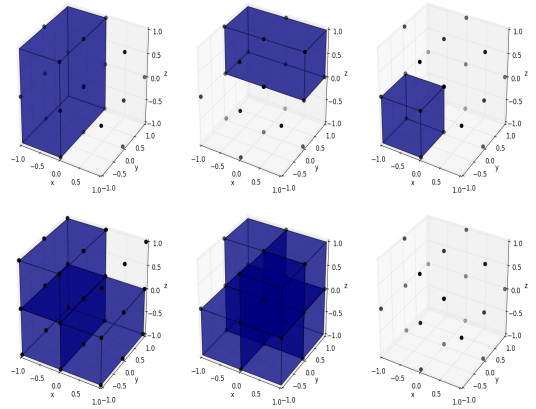
  - Collision: particles collide a each lattice node
  - Steaming: particles move according to discrete velocities
- Works well with complex geometries and scales well on massively parallel systems [1].

[1] Randles et al., Supercomputing 2015, 2015

Regularized Boundary Conditions

- Analytical solution for the set of linear equations for both Dirichlet and Neumann boundary conditions
- Recognized different types of boundary's during the preprocessing and encoded
  - Concave faces, edges, and corners
  - Convex edges and corners
  - Inlets and outlets



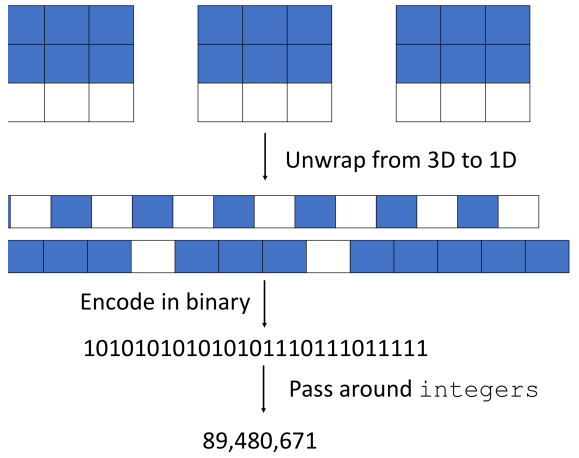


$$\sum_{i \in I} f_i H_{\alpha,\beta,i} = \sum_{i \in I} \hat{f} H_{\alpha,\beta,i}$$

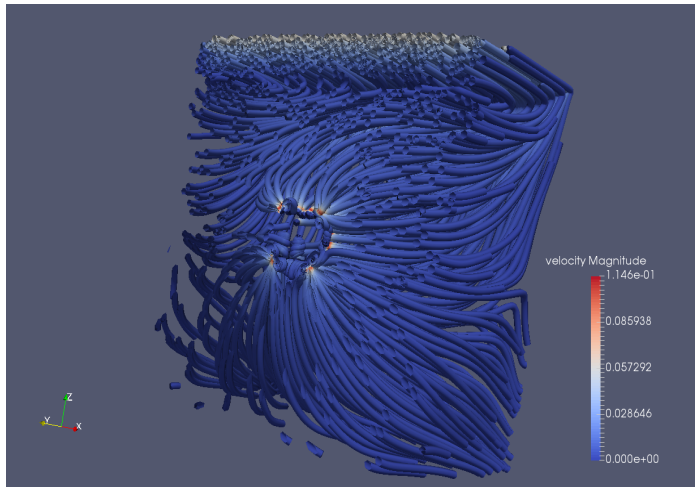
$$\sum_{i \in O} f_i(r + c_i \delta t, t + \delta t) = \sum_{i \in I} f_i(r,t)$$

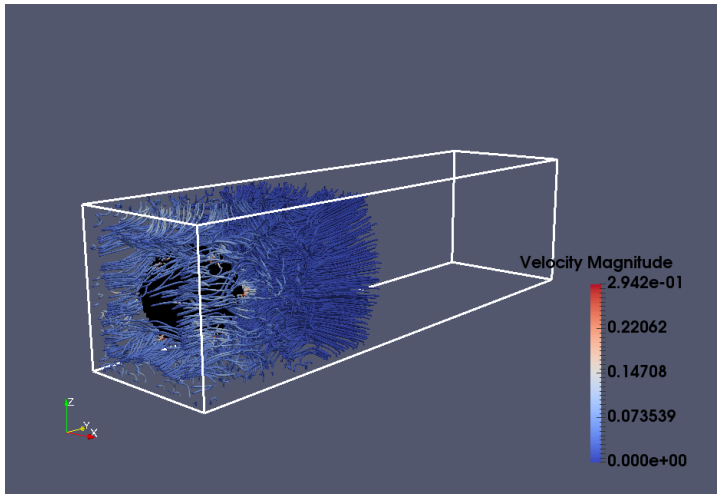
$$I = \{i \| f_i \text{is an incoming distribution}\},$$

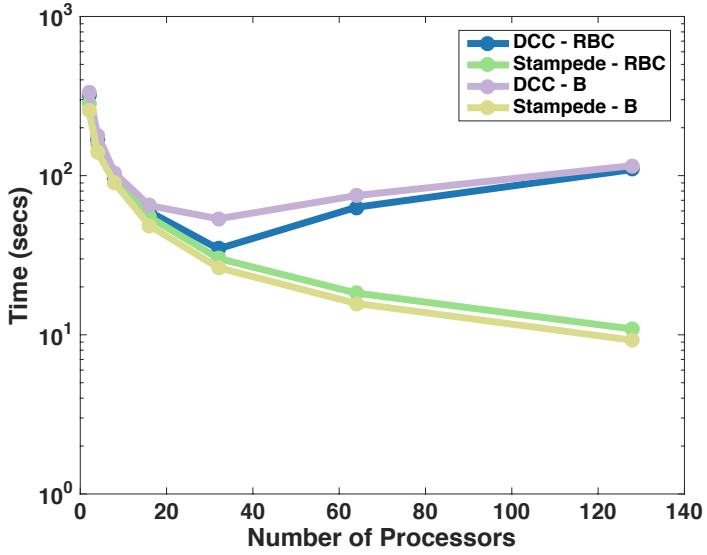
$$O = \{i \| f_i \text{is an outgoing distribution}\},$$



Results: Modified lid-driven cavity flow, flow around the sphere and scaling results







Maximum Memory (MB)

Core Count	Regularized BCs	Bounce Back
16	94.98	91.01
128	13.99	13.41

Future work

- Flow around the sphere
  - Fix the numerical errors
  - Simulations will require the smallest resolution possible in Harvey to model the vortex formation and shedding
  - Continue to optimize implementation of regularized boundary conditions

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