Fluid Simulation

Reem Alghamdi

Navier-Stokes equations for incompressible flow

$$\frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} + \frac{1}{\rho} \nabla p = \vec{g} + \nu \nabla \cdot \nabla \vec{u}, \tag{1.1}$$

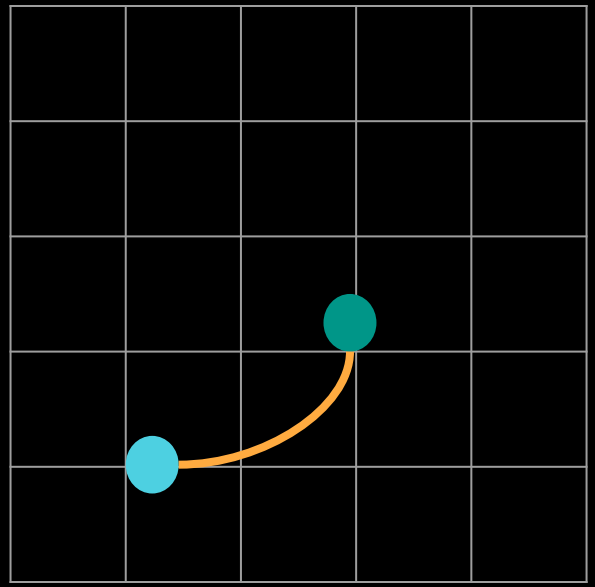
$$\nabla \cdot \vec{u} = 0. \tag{1.2}$$

Algorithm

- Advection of Fluid
- Diffusion
- Pressure Solve
- Advection of Diffusion of others
- Boundary set

Advection

- Describes how the fluid move things (itself included)
- Given some quantity Q on our simulation grid, how will Q change Δt later?
- q(x, t+Δt) = q(integrate(x, velocity(x, t), Δt) , t)
- integrate(x, velocity(x, t), dt):
  - Euler
  - RK2
  - RK4



Pressure solve

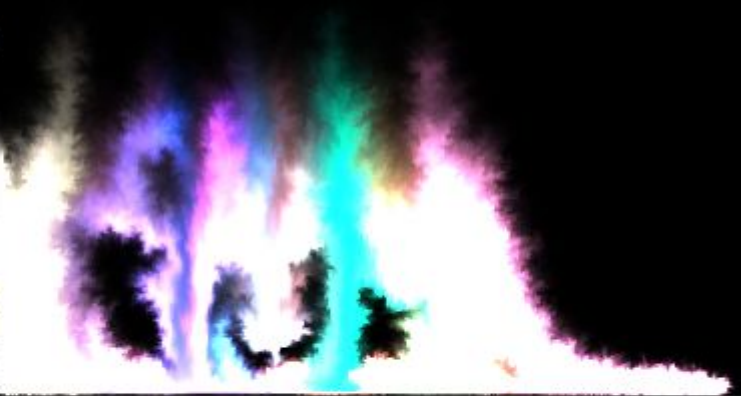
- Poisson Equation
- Solve analytically
  - Jacobi
  - Gauss-Seidel

$$w = u + \nabla p$$

$$\nabla . w = \nabla . (u + \nabla p)$$

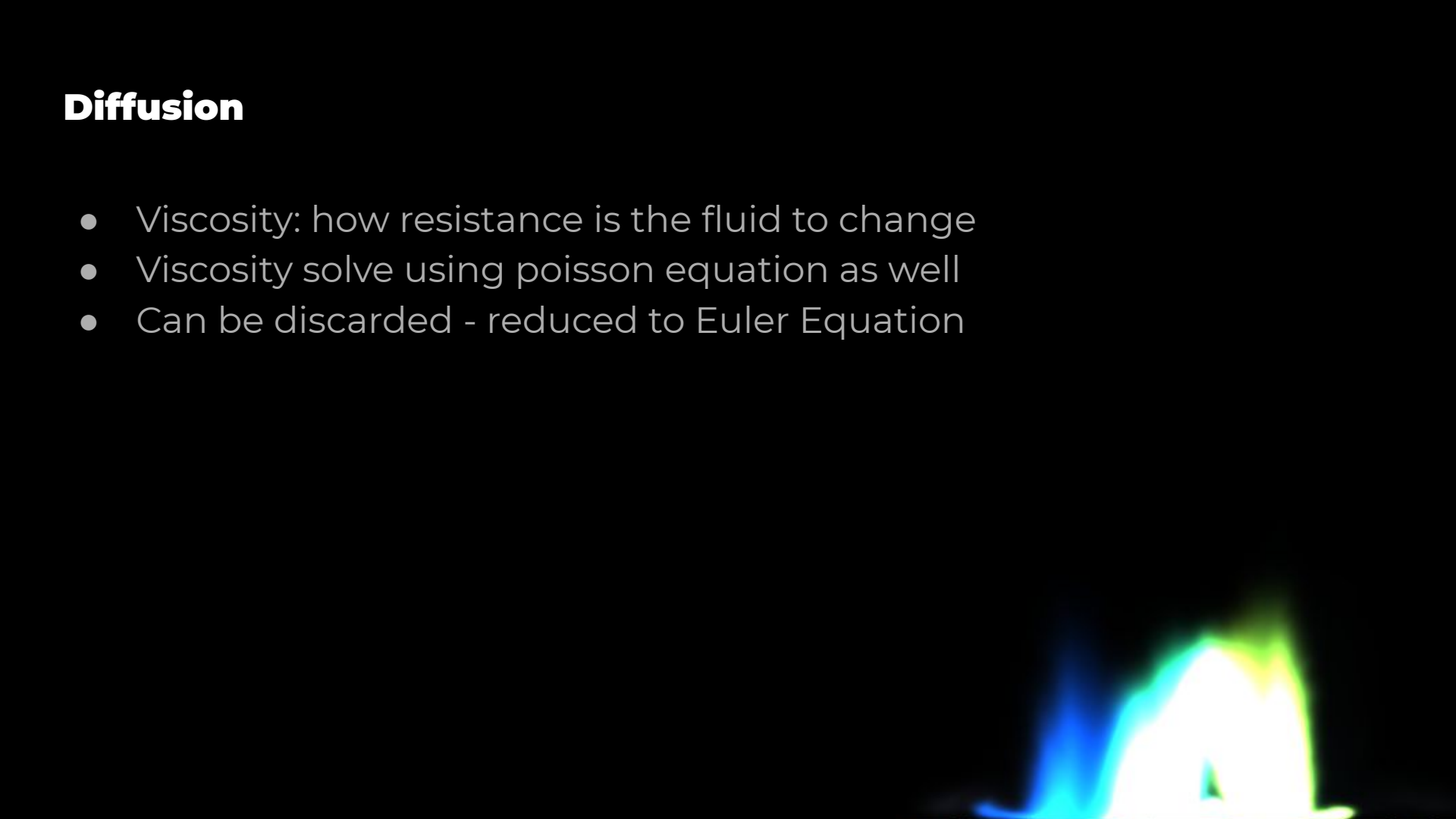
$$\nabla . w = \nabla . u + \nabla^2 p; \quad \nabla . u = 0 \quad (2)$$

$$\nabla^2 p = \nabla . w$$



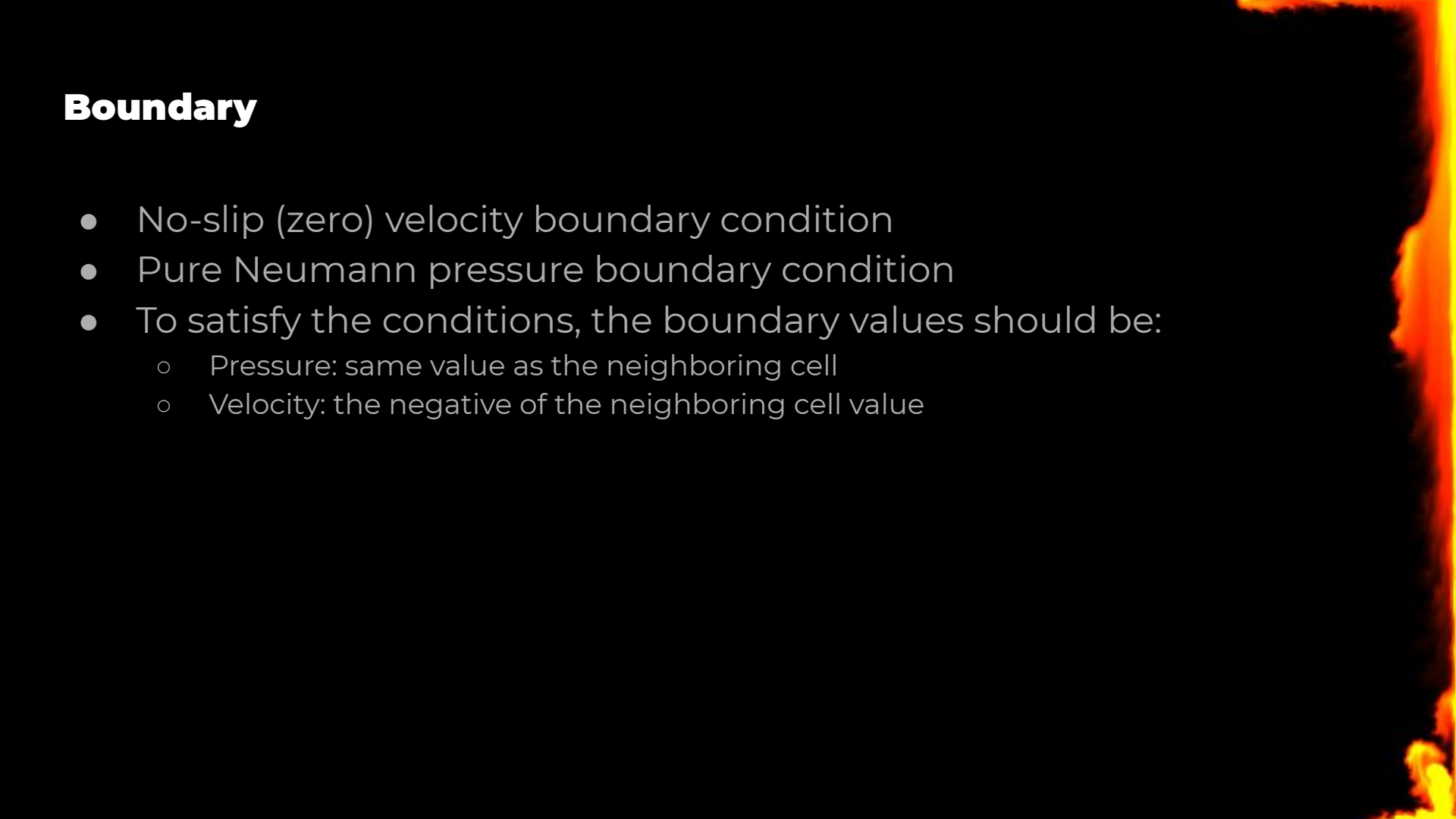
Diffusion

- Viscosity: how resistance is the fluid to change
- Viscosity solve using poisson equation as well
- Can be discarded - reduced to Euler Equation



Boundary

- No-slip (zero) velocity boundary condition
- Pure Neumann pressure boundary condition
- To satisfy the conditions, the boundary values should be:
  - Pressure: same value as the neighboring cell
  - Velocity: the negative of the neighboring cell value



Technical details

- Made using
  - OpenGL for display
  - imgui for UI
  - Fluid solve available in CUDA and CPU
- Performance difference is too great

github.com/reem-codes/fluid_simulation

Results

github.com/reem-codes/fluid_simulation

github.com/reem-codes/fluid_simulation

References

- Braley, Colin and Adrian Sandu. Fluid Simulation For Computer Graphics: A Tutorial in Grid Based and Particle Based Methods, 2009.
- Bridson, Robert. Fluid Simulation for Computer Graphics. CRC Press, 2016.
- Harris, Mark. “Chapter 38. Fast Fluid Dynamics Simulation on the GPU.” GPU Gems. Nvidia, https://developer.nvidia.com/gpugems/gpugems/part-vi-beyond-triangles/chapter-38-fast-fluid-dynamics-simulation-gpu
- KAUST’s GPU and Scientific Visualization slides :D

github.com/reem-codes/fluid_simulation

Thank you!