Informatics

Adaptive Sampling in Position Based Fluids

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Problem Statement

Position Based Fluids (PBF) is a fluid simulation method in the Position Based Dynamics (PBD) framework. Fluids are represented by particles. Large amounts of fluid require many particles, taking up storage space and increasing the computation time.

Our method extends PBF to allow particles to represent varying amounts of fluid. Regions of high interest can be represented at the highest particle resolution, while the resolution in other regions is reduced by using fewer particles, where each of these fewer, but larger particles represents a larger amount of fluid.

Regions of High Interest

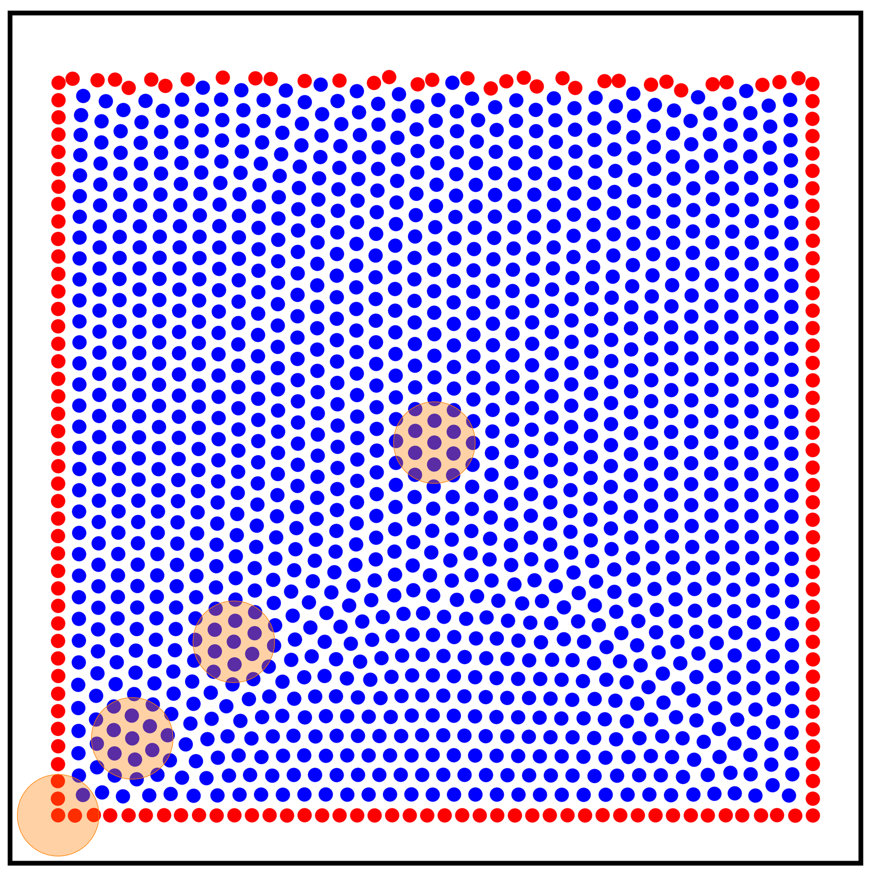
We chose the fluid boundary as the region of high interest for two reasons:

- Only the fluid boundary is visible in rendering (reflection, refraction)
- We expect turbulence at the boundary between fluid and obstacles

Kernel

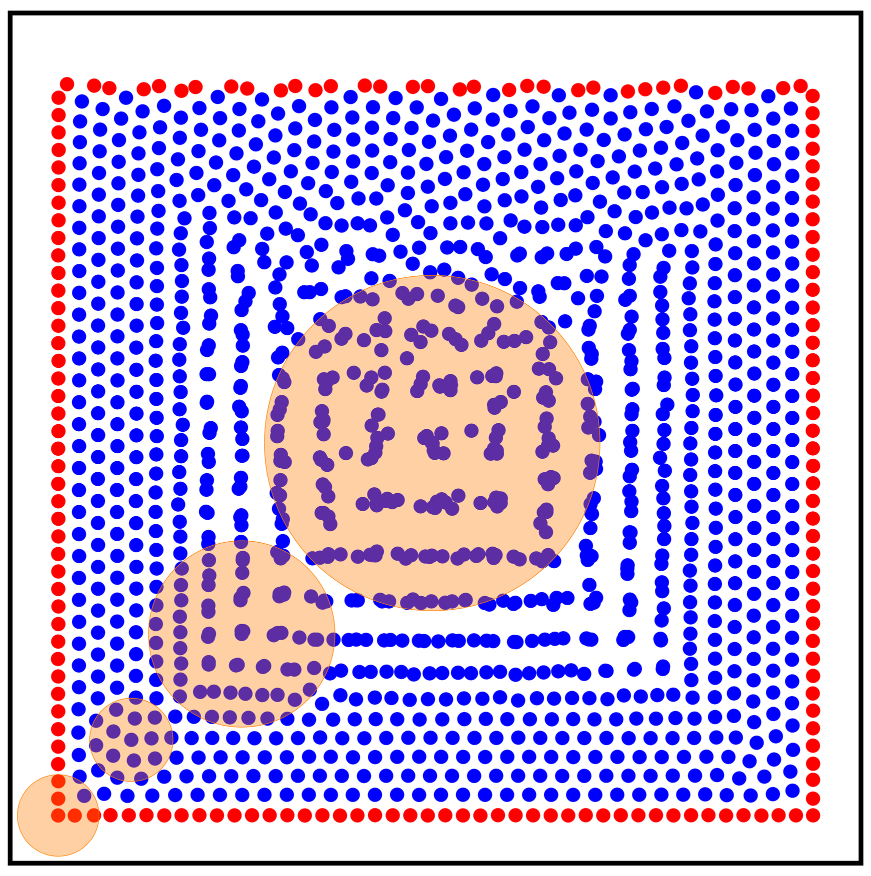
PBF uses kernels to estimate the fluid density based on the particles. Kernels are placed at each particle position and must contain surrounding neighbor particles for accurate density estimation. With fewer samples (particles), neighbors are further away ⇒ larger kernel width needed

Adaptive Resolution



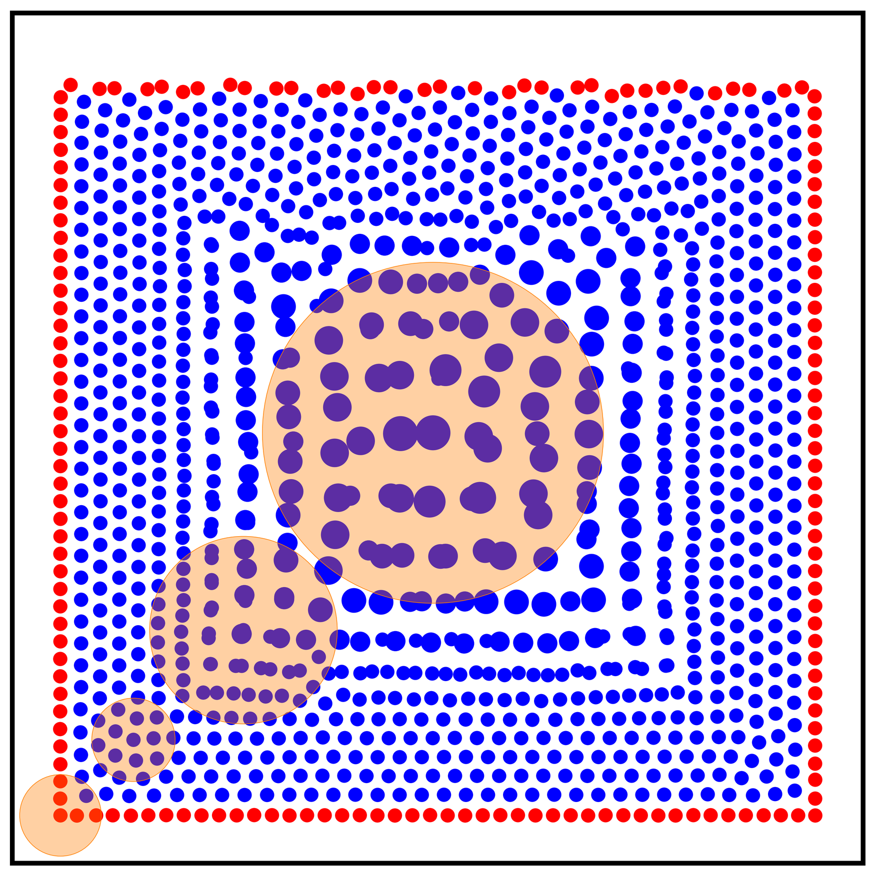
Every Particle represents the same amount of fluid and uses the same kernel width

Enlarge kernel width for particles with higher boundary distance



After some time, we let the particles form clusters deep inside the fluid, while the boundary stays unaffected

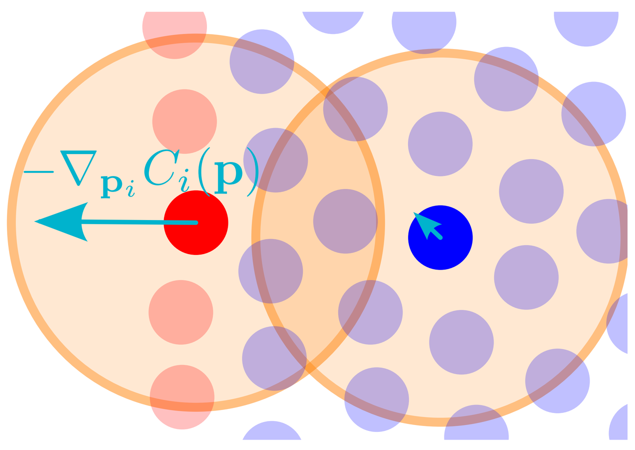
Gradually merge clustered particles



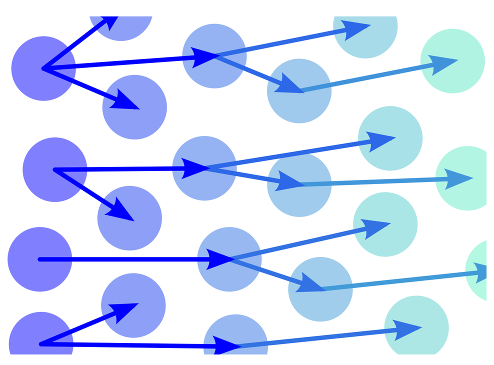
The fluid resolution has decreased in the center, while the boundary stays detailed

Boundary

PBF requires the computation of the density gradient $\nabla_{\mathbf{p}_i} C_i(\mathbf{p})$ for every particle $\mathbf{p}_i$. We use this gradient to find the boundary: inside the fluid, the density does not change much in any direction, but at the boundary, the gradient is larger.



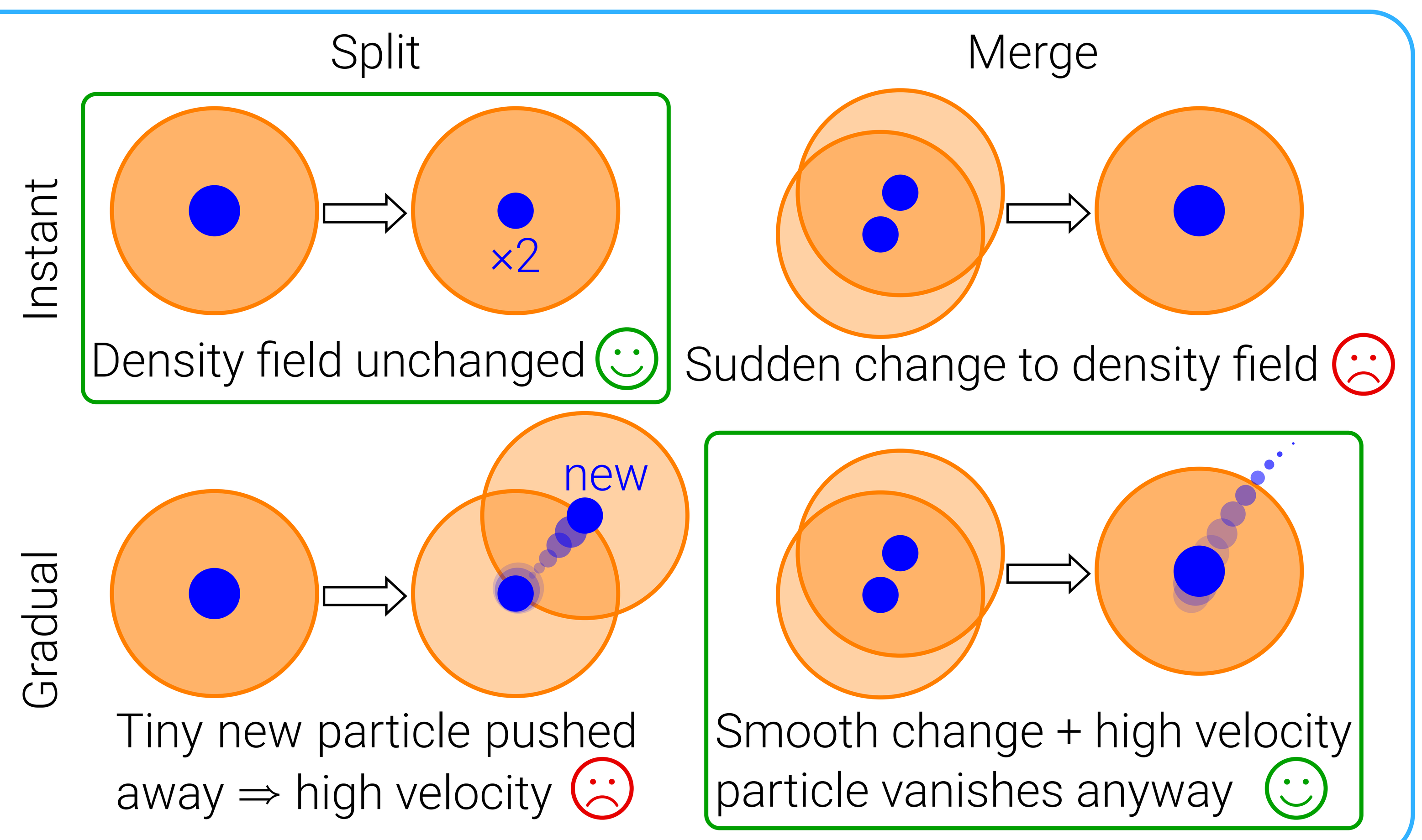
We propagate the distance from the boundary step-wise deeper into the fluid using the neighborhood data. We perform just one iteration per timestep to reduce the workload.



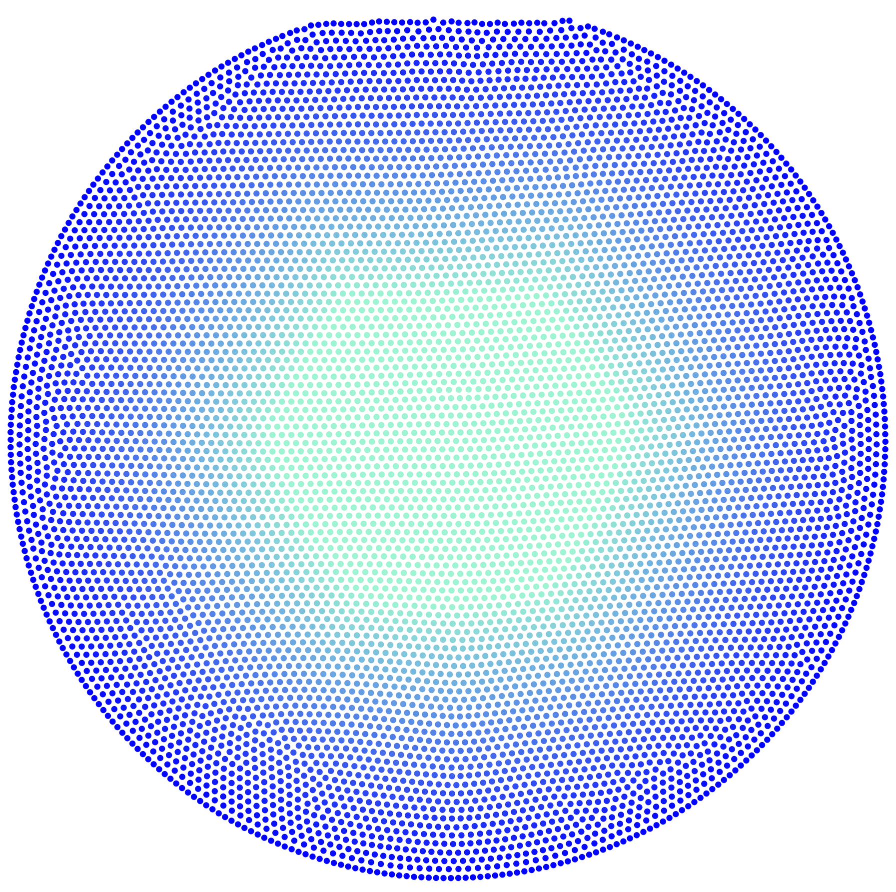
Split & Merge

Splitting & merging should cause as little disturbance as possible.

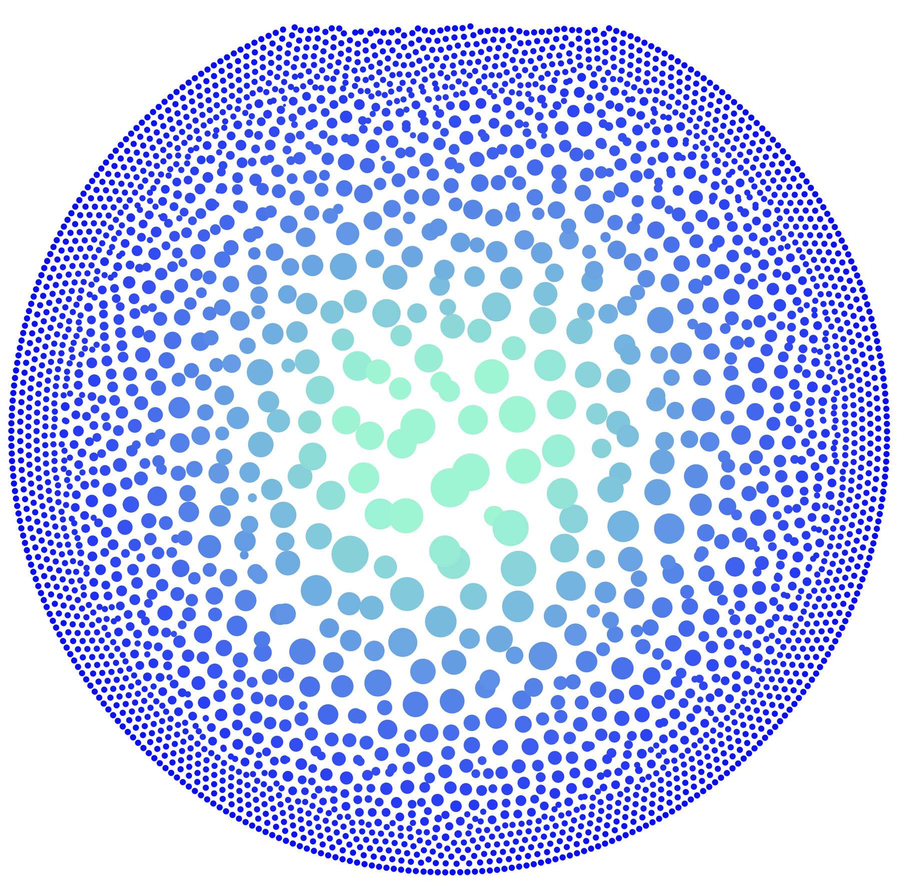
Instead of doing merging & splitting instantly, they can be performed gradually. Instant splitting & gradual merging showed the best results.



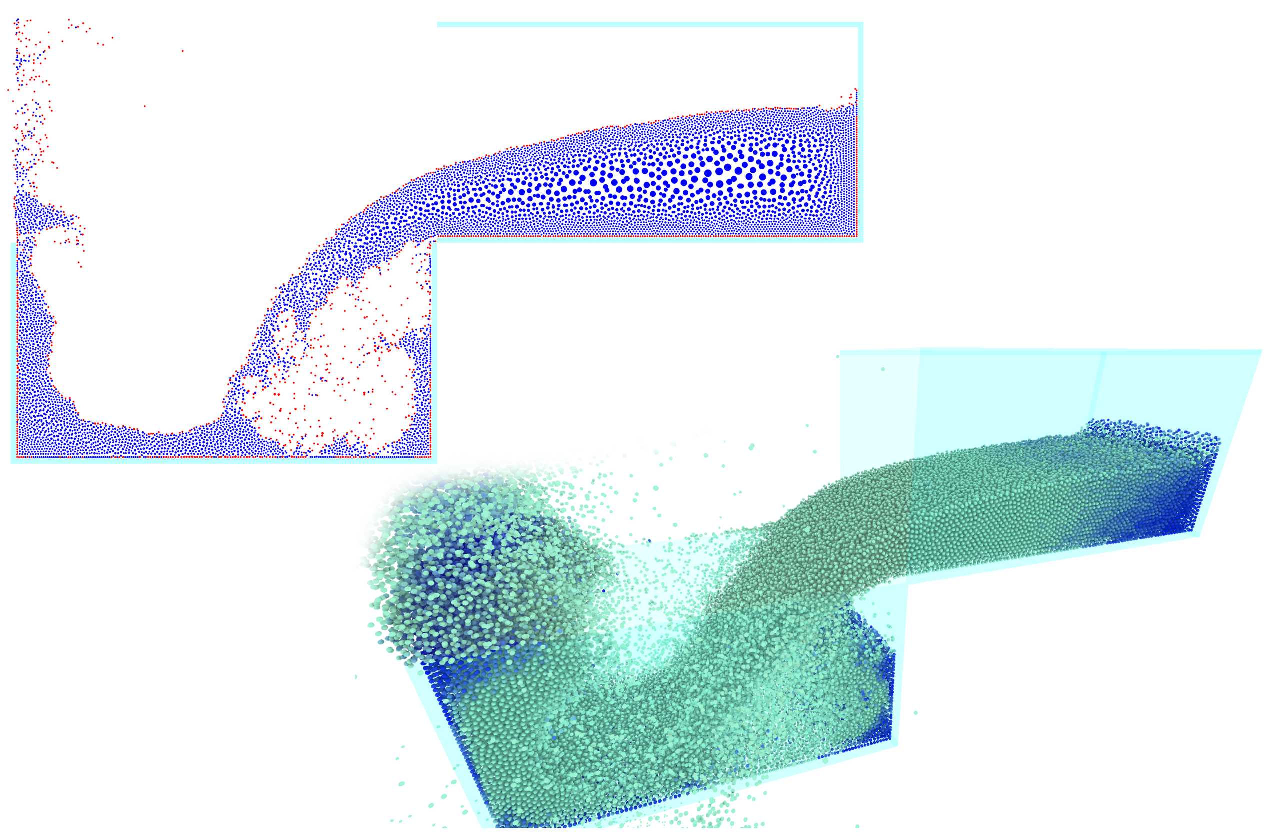
Results



Basic PBF
7853 particles
92 200 neighbor pairs



Our method
3154 particles
66 011 neighbor pairs



Our method in 2D and 3D

In both variants, 2D and 3D, the "big" particles in the center of the respective upper pool get split so that the stream into the respective lower pool is modeled in the highest precision.