Animation

Physics Simulation – Real-Time Water

Motivation

SPH Simulation Data

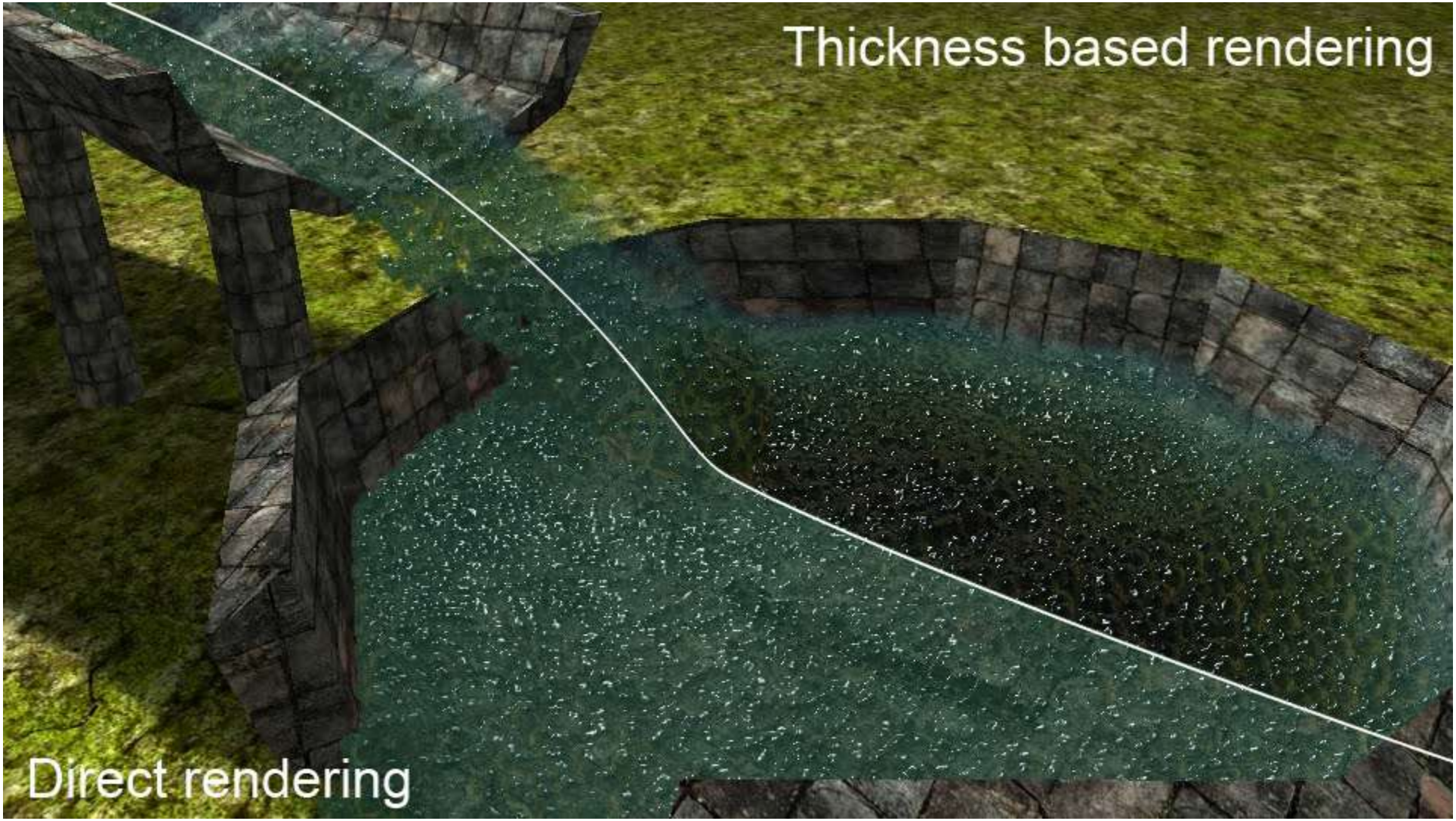
- SPH = Smoothed Particle Hydrodynamics
- Numeric method to solve hydrodynamic equations
- Non-sorted 3D point cloud
- Fluid is able to flow everywhere
- Difficult to extract surface for rendering
- Available in PhysX

Direct Rendering of SPH Simulation Data

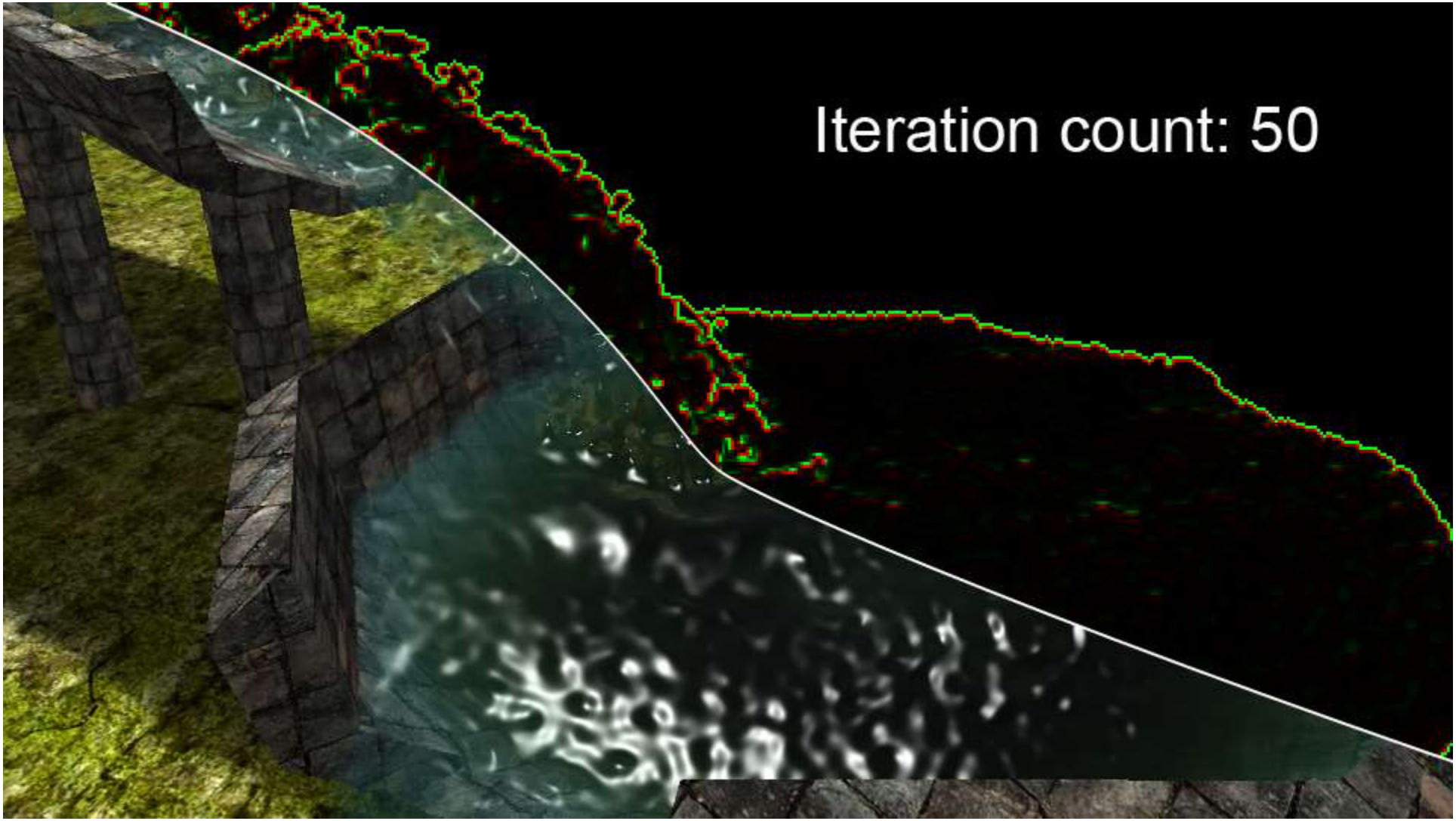
Approaches

- Screen space fluid rendering with curvature flow.
  - van der Laan et al. [vdLGS09]
  - Thickness based rendering
  - Screen-space curvature flow filtering
- Simulation of two-phase flow with sub-scale droplet and bubble effects.
  - Mihalef et al. [MMS09]
  - Weber number thresholding
- A Layered Particle-Based Fluid Model for Real-Time Rendering of Water
  - Builds on [vdLGS09]
  - View dependent filtering
  - Volumetric Foam

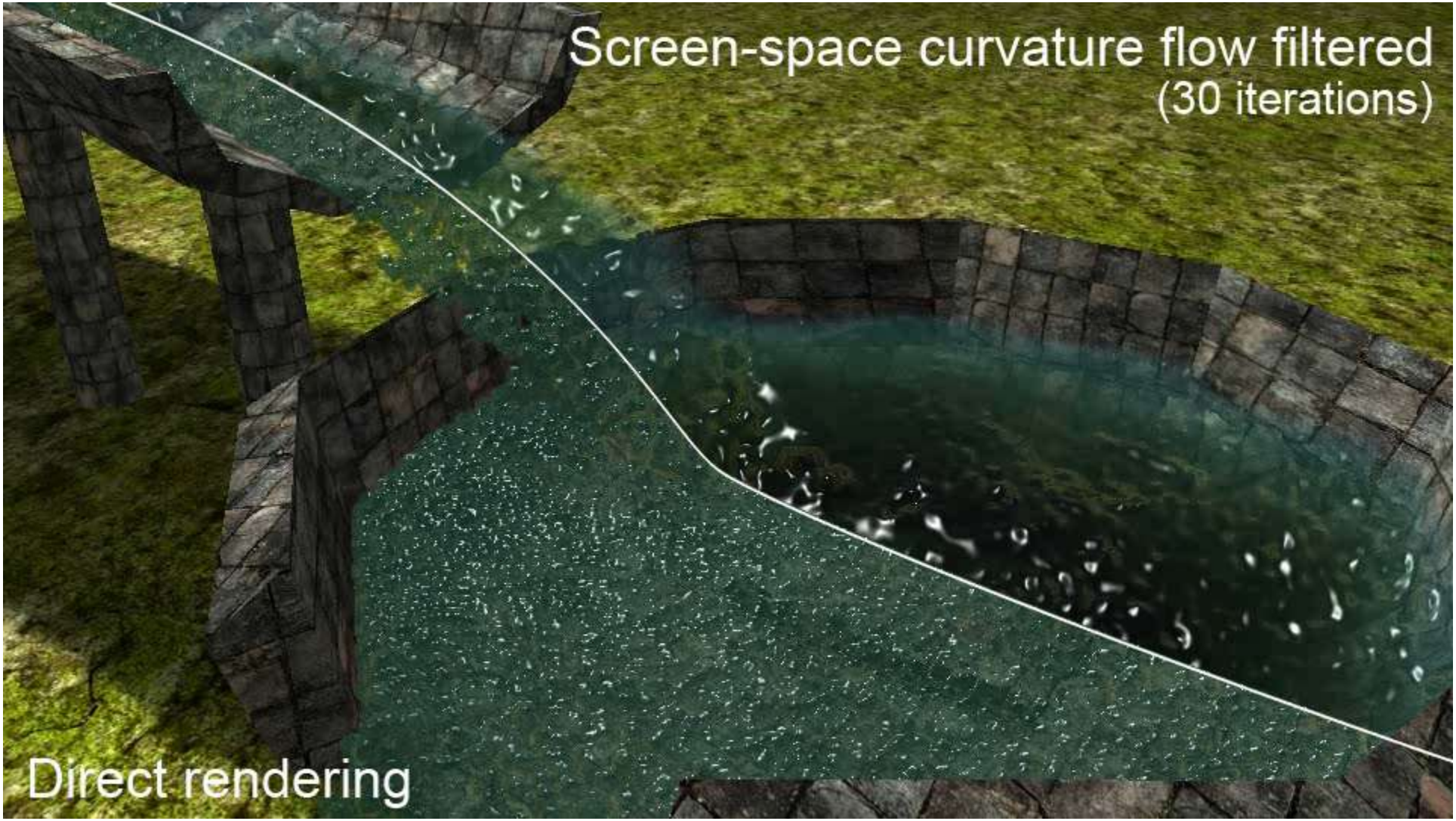
Thickness Based Rendering



How to smooth the surface?



Screen Space Curvature Flow



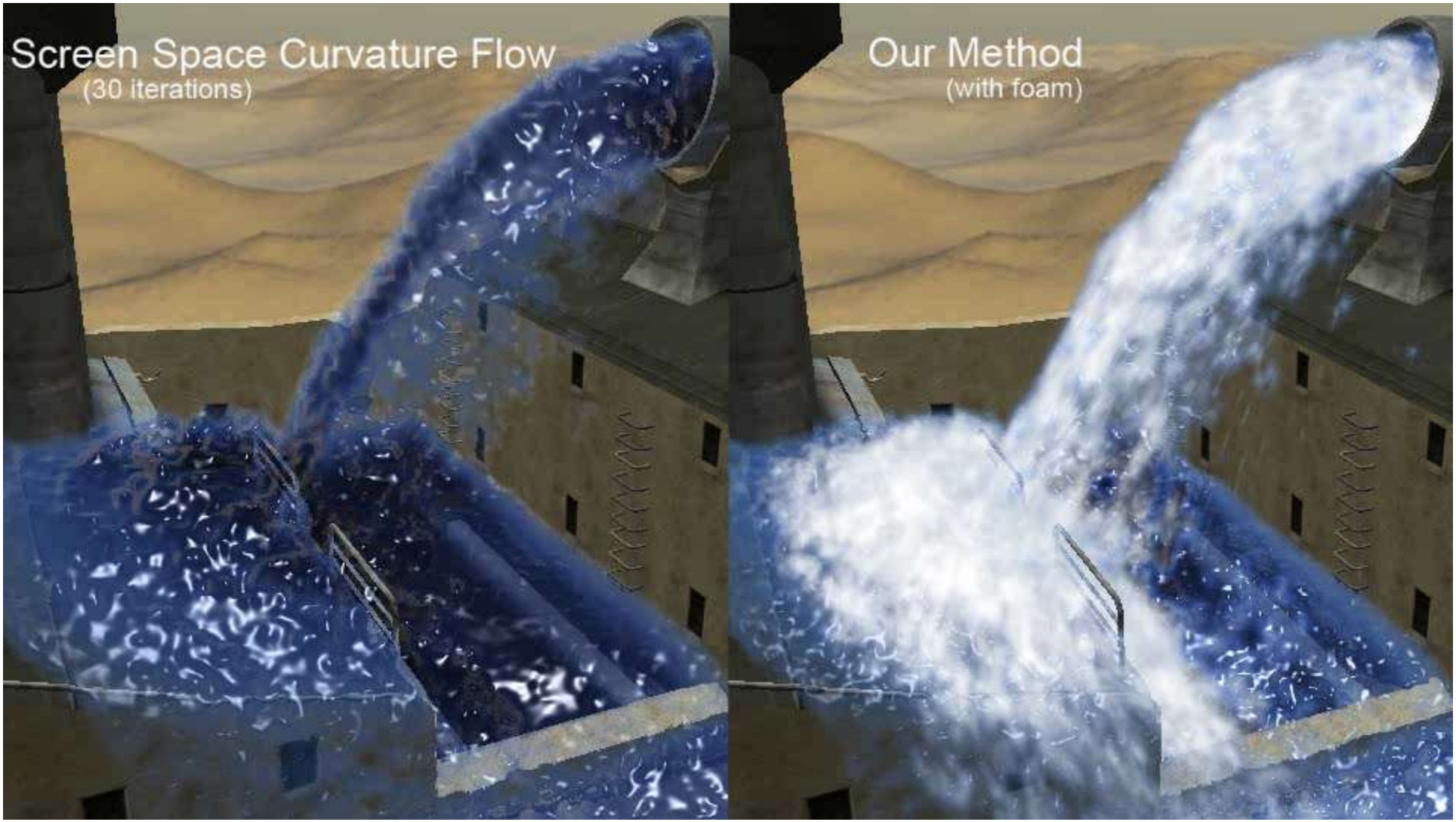
Smoothing Artefacts

Adaptive Curvature Flow

- Interpret each integration step as a filtering step with a 3x3 kernel in view space
- Vary number of iterations depending on the view space distance z

Improved Filtering

Real-Time Foam



Definitions

- Foam: trapped air bubbles in the liquid
- Two main effects in real-time
  - Spray or bubbles onto the water surface
  - Foam that occurs behind a water surface

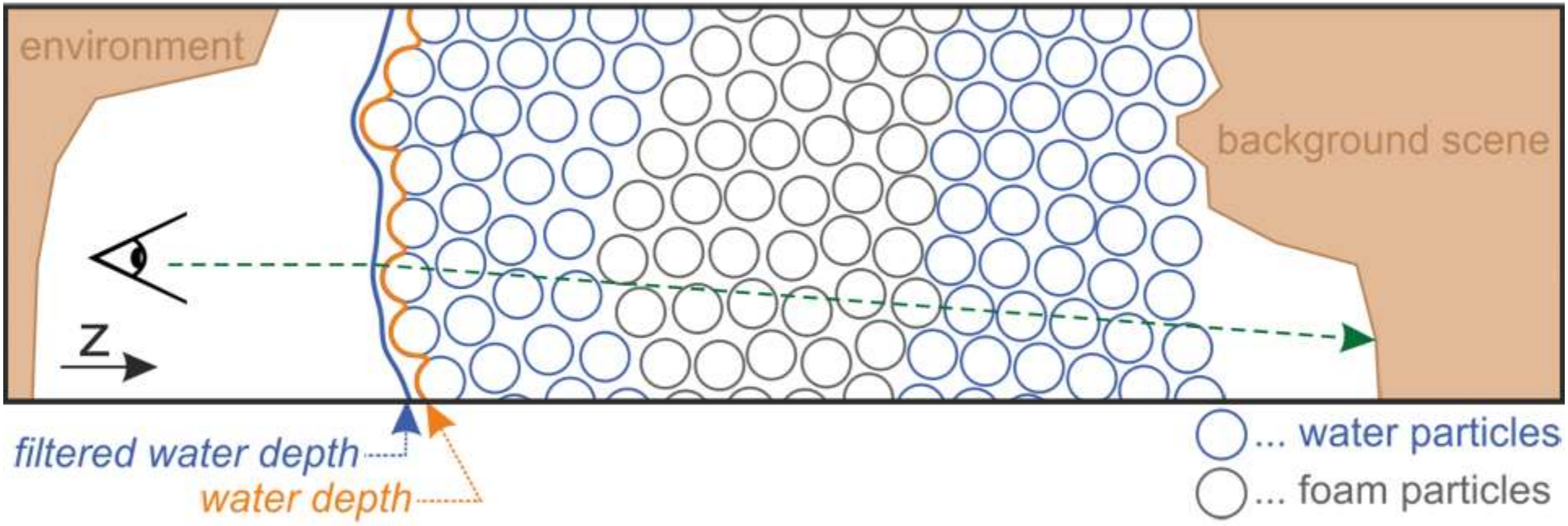
Foam Formation

- Foam formation
  - Based on Weber number thresholding
  - Physical formula used in off-line systems
  - Classify particles as water or foam

Weber Number Threshold

Rendering of Foam

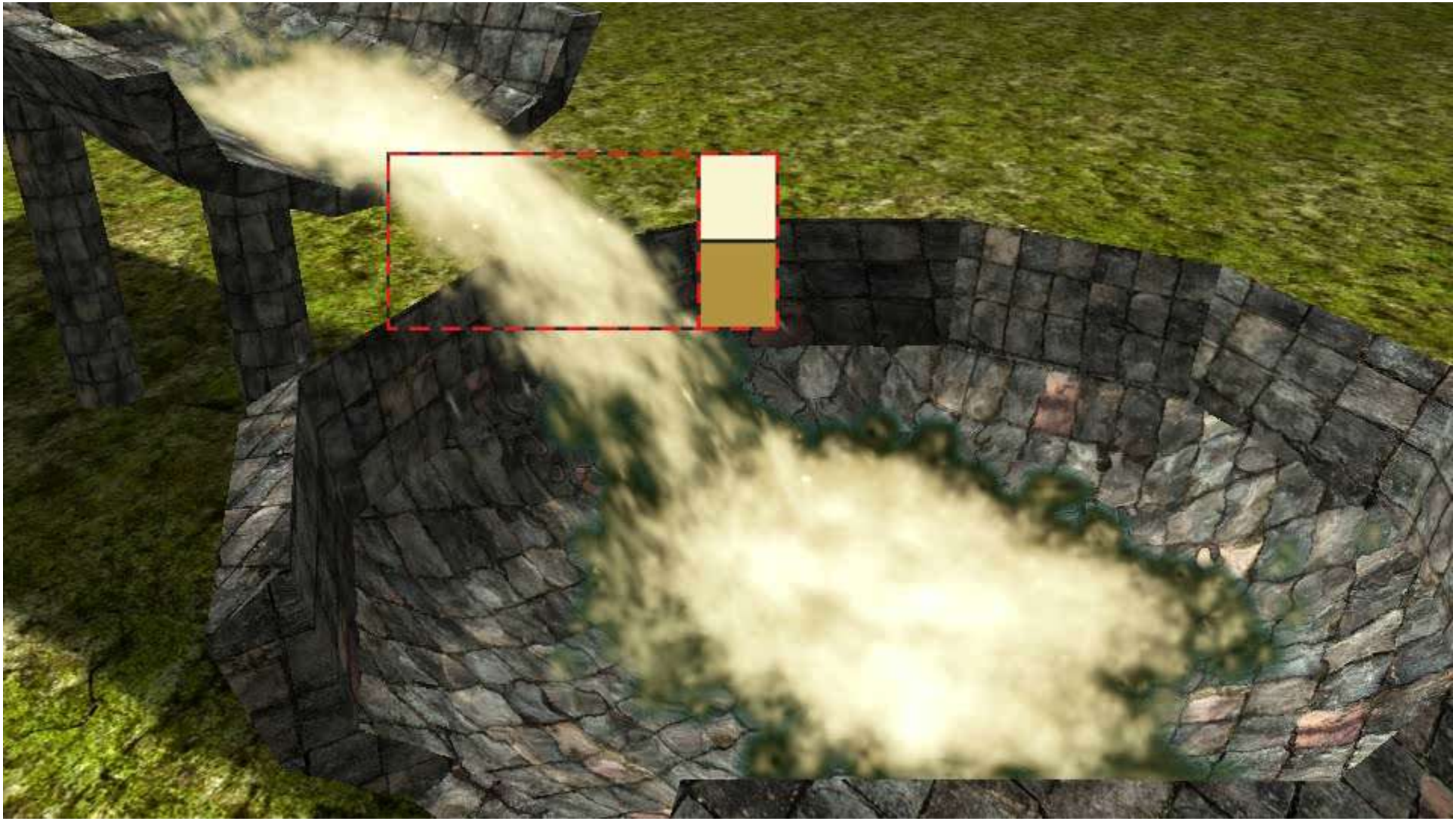
Scene Configuration and View Ray



Background Scene

Back Water Layer

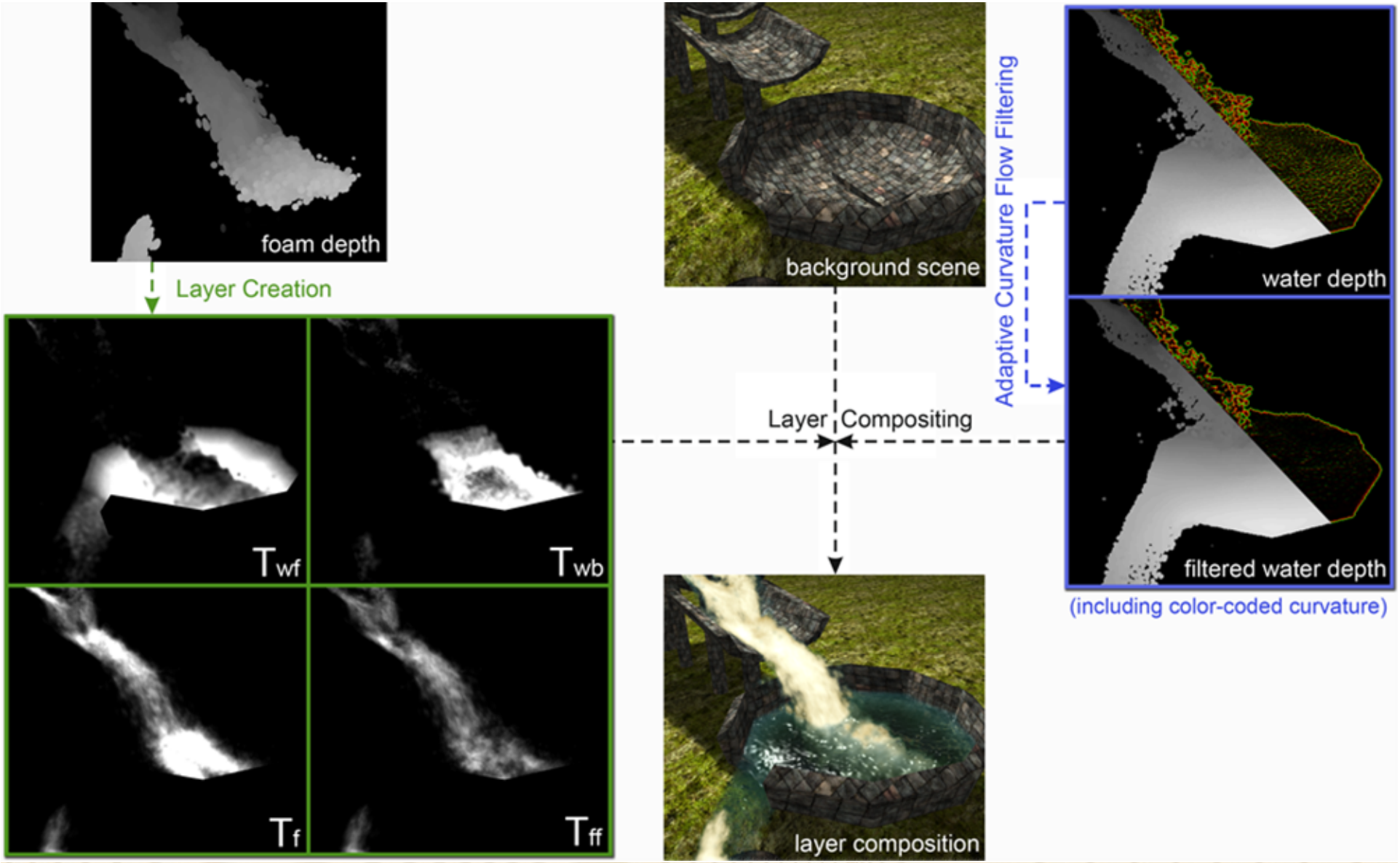
Foam Layer



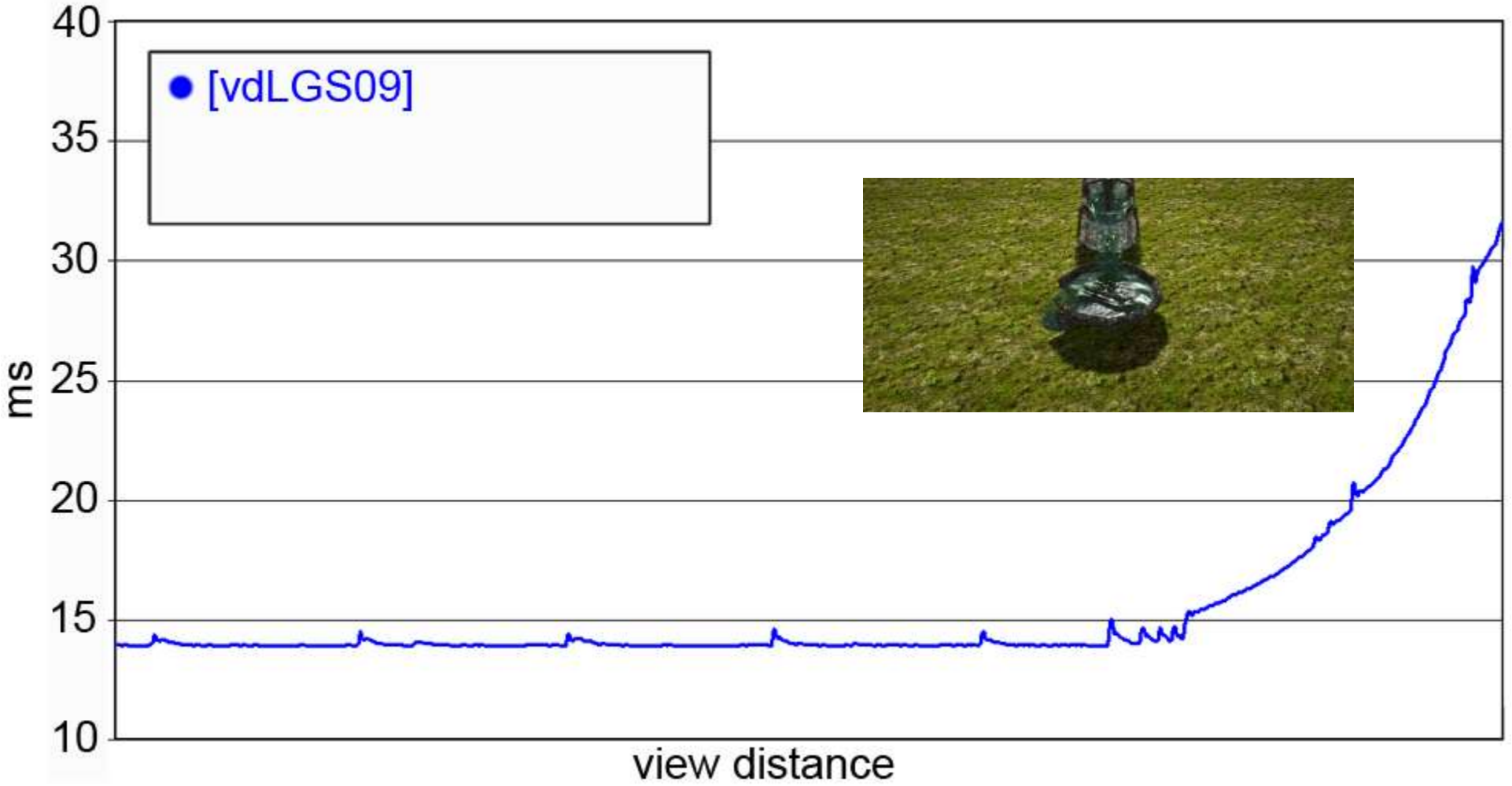
Front Water Layer

Reflection and Specular Highlights

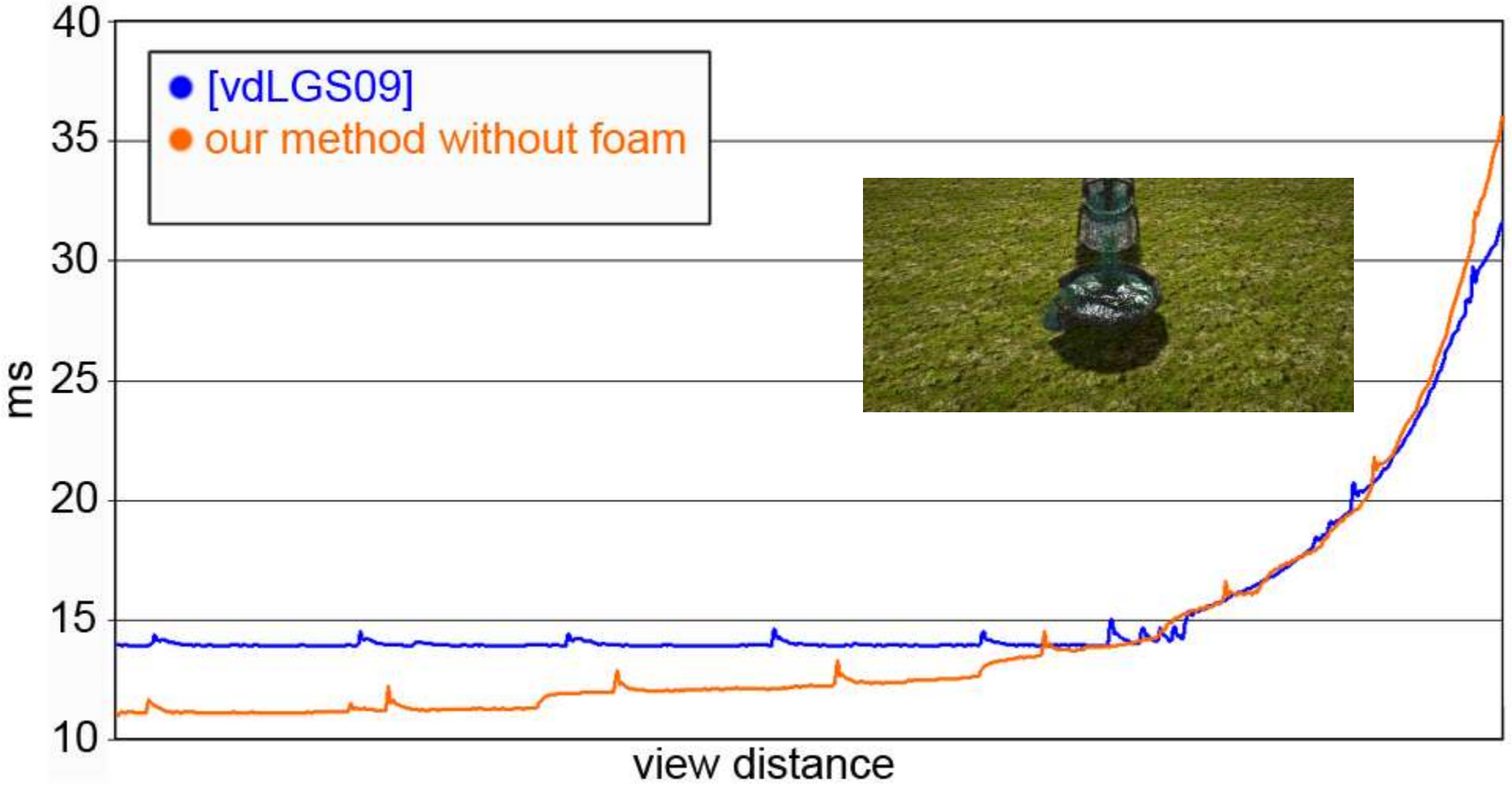
Algorithm Summary



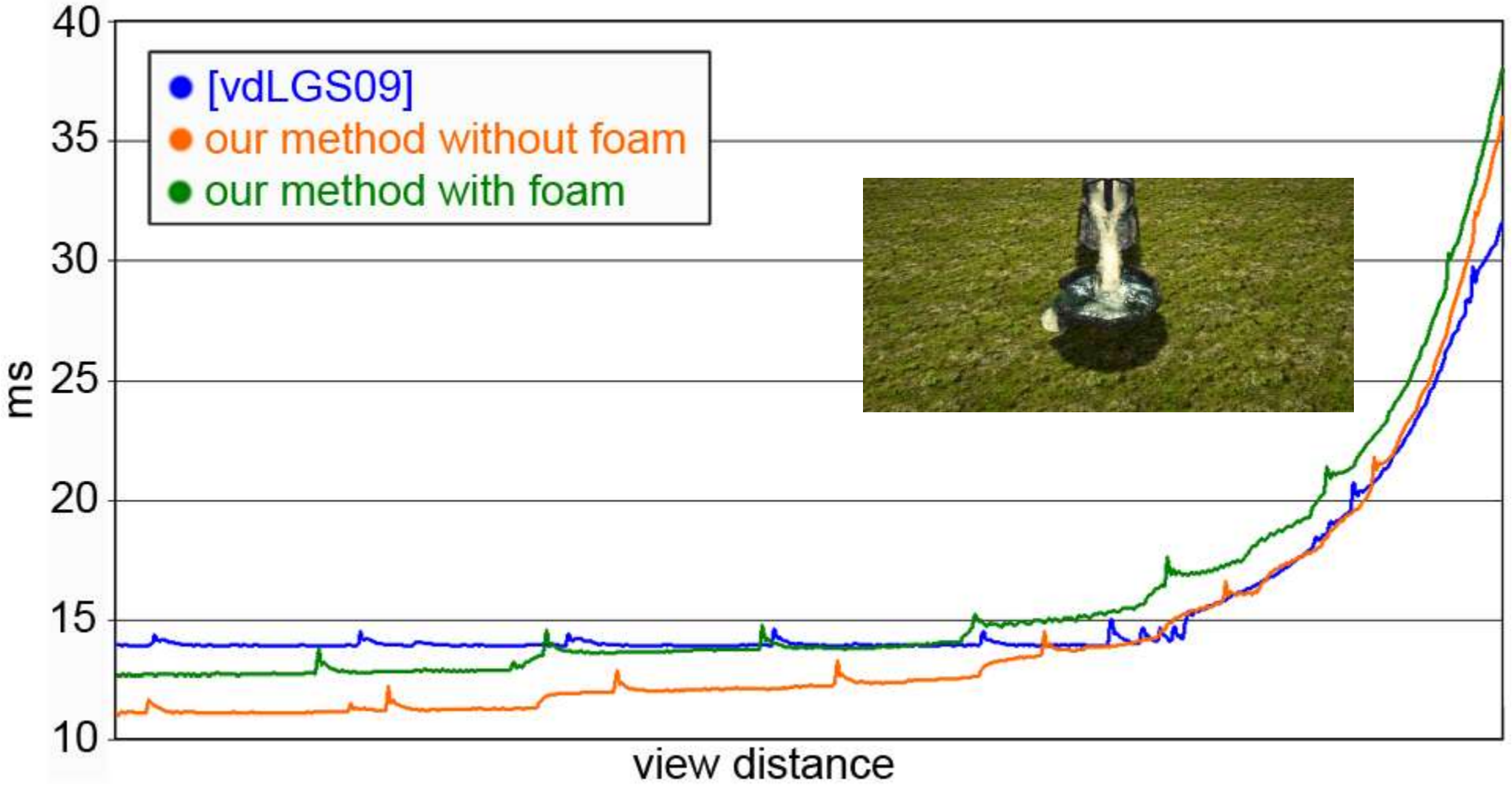
Performance Comparison



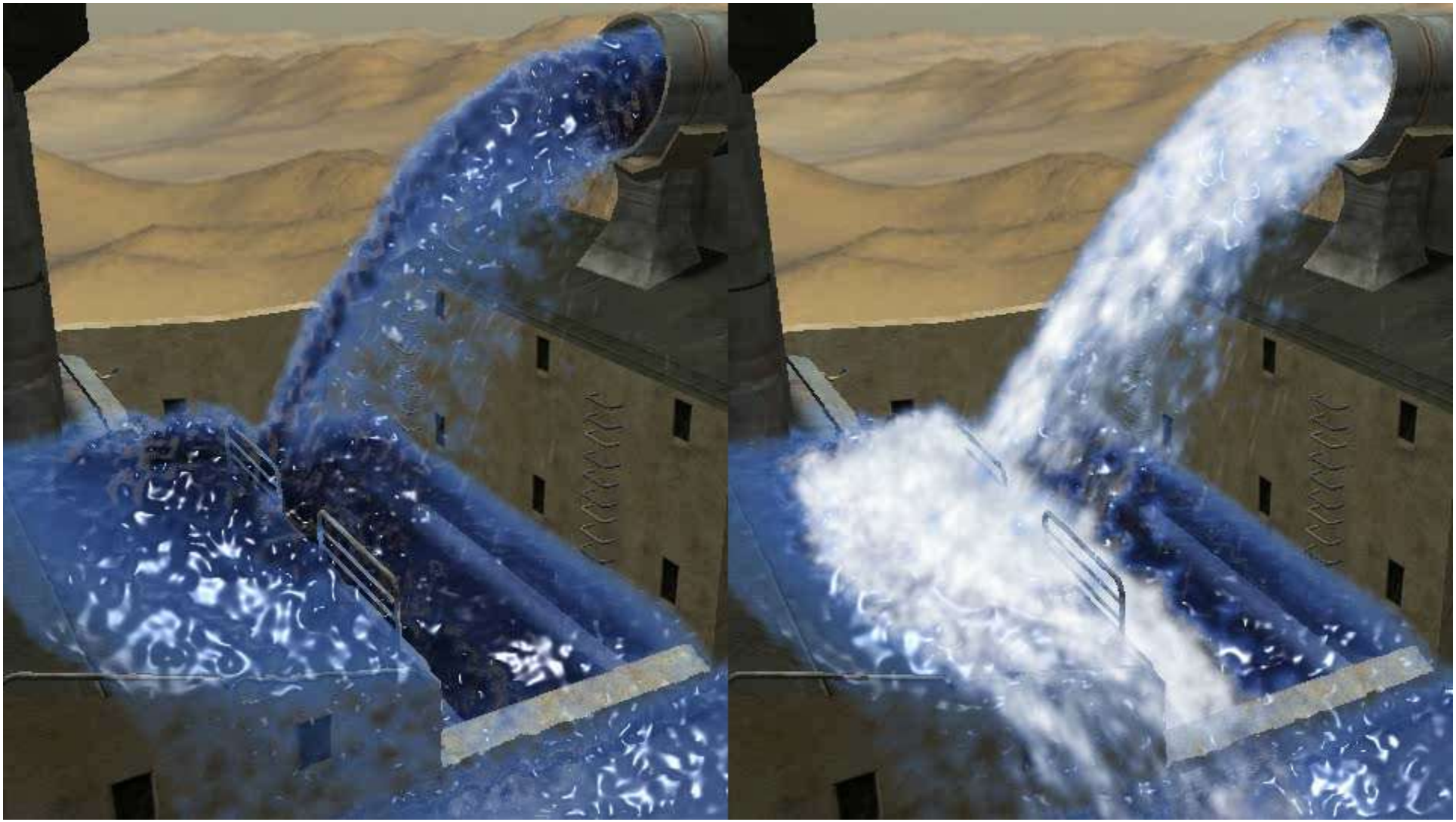
Without Foam



Including Foam



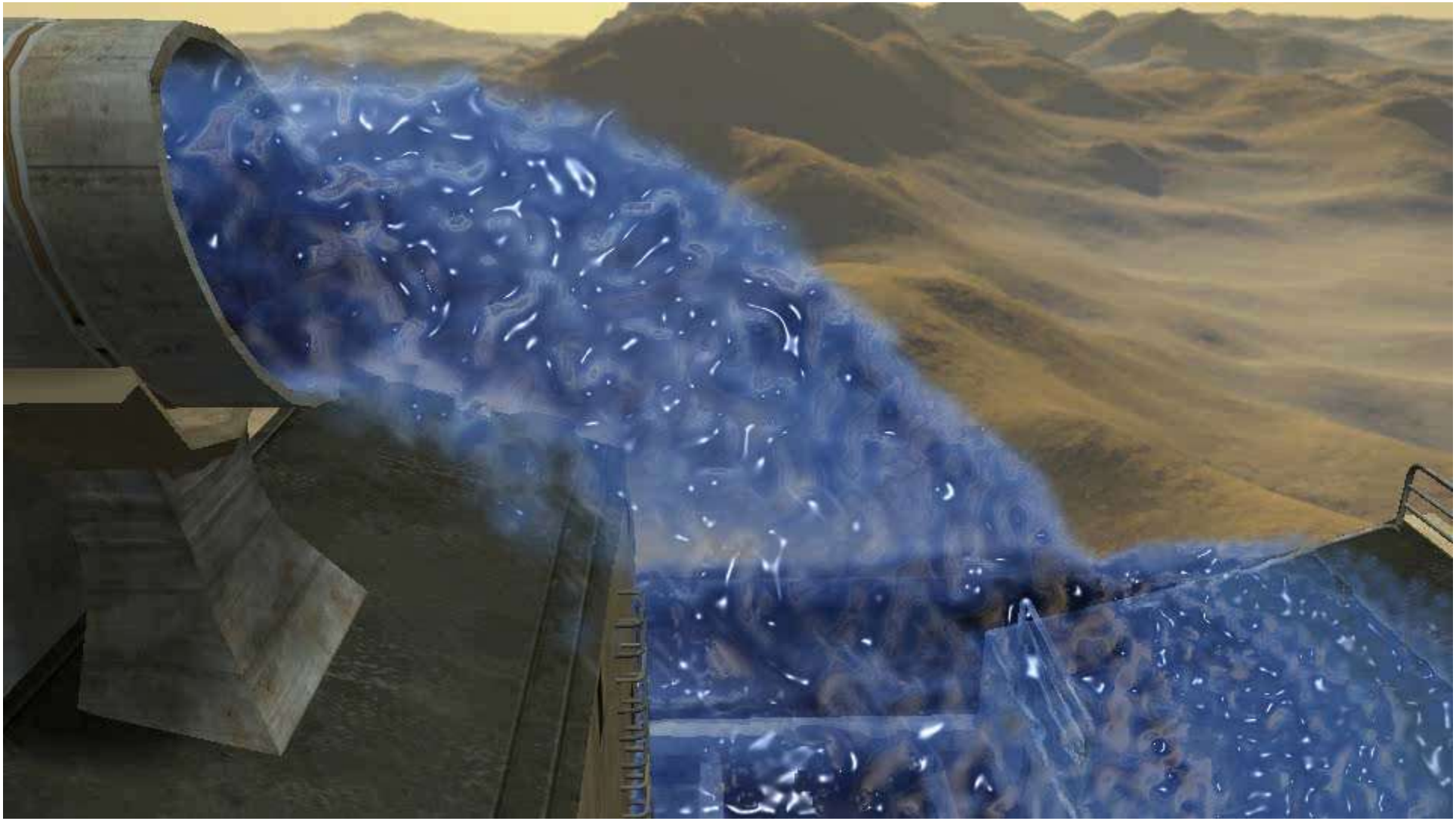
Comparison – w/o Foam – with Foam



Dynamic Scenes

Ground Truth

Limitation



Conclusion

- Rendering particle-based fluids with volumetric foam in real time

- Adaptive curvature flow smoothing
- Physically guided foam rendering
- Layered compositing