Faculté des Sciences et Ingénierie - Sorbonne université

Computer science masters - IMA

IG3D

Project abstract

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Two-scale SPH abstract

1.1 Introduction

Fluid dynamics simulation is a field that is on the crossroads of physics and computer science. While the physical aspects are based on rules and equations that are known and clear, the computational matter continues to withstand innovation from researchers in order to better render the phenomenas that are described by those equations. One major challenge that is being faced is the computing power, as high simulation resolutions are required in order to produce physically precise and visually appealing results. The paper we are going to discuss in this report is one attempt among many others to solve that problem.

Written by Solenthaler and Gross from the university of Zurich [5], it aims to speed up the rendering of high precision fluid simulation using a two-scale method, which allocates high computing resources to the regions where complex flow behavior happen in the fluid.

1.2 Smoothed Particle Hydrodynamics

SPH is a mesh-free computational method for simulating the dynamics of fluids. It has been used in many fields of research, including astrophysics and oceanography.[2]

It works by discretizing the fluid into a number of elements called particles, each one having a set of quantitative properties which are calculated after each

time step of the simulation, and this by taking in consideration the properties of all the neighbouring particles inside a determined radius.

1.3 Related Work

When using SPH, the simulation's quality is directly defined by the **number of particles** that are used to discretize the fluid, and since the calculations are based on neighbour searches, the computing cost can scale up very quickly.

One way to optimize the performance is by allocating computing resources to **complex flow regions** like in [Adams et al. 2007][1] where adaptive particle sizes have been used, as articles are dynamically split and merged, but it created problems related to having particles of different sizes interacting with each others and altering the physical phenomenon that is being simulated.

1.4 The two-scale simulation method

This method is based on calculating two different simulations that have different resolutions. First, a basic low resolution simulation is computed for all the particles. Then, a region of interest/complex behavior is determined and the subset of particles is simulated in a higher resolution. This subset can be determined dynamically or by defining a region of the simulation's scene in which complex behavior occurs and finer details are required. Finally, the two simulations are merged for the final rendering.

1.5 Implementation

Our implementation of the method is based on the observation that computing two seperate simulations for different parts of the fluid can lead to inaccuracies regarding the restitution of the physical phenomenon that is being simulated, as new particles are constantly being created and removed, and basically some particles are not being computed the same way as others.

We chose as an example the simulation of a star relaxing into a stable state based on a work by P. Mocz [3] [4] , and adapted the two-scale method to compute all of the particles the same accurate way as we gave particular attention to **keeping the integrity of the dynamic model**, and keeping the idea of

a region of interest by rendering only a subset of the particles outside of that region.

1.5.1 Results

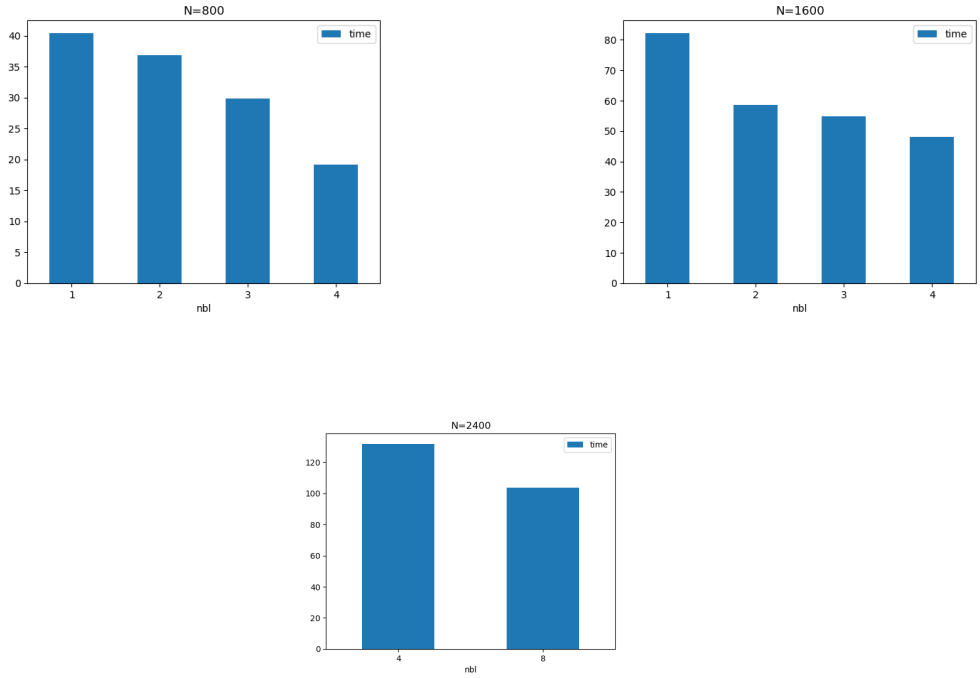

FIGURE 1.1 – Evolution of the execution time while varying some resolution parameters

These graphs, displaying the evolution of the execution times of different discretization resolutions (N) while varying the resolution ration between inside and outside the region of interest (nbl), (value of one being equivalent to one-scale simulation), clearly shows the gain in computational time offered by our implementation.

Moreover, our method has allowed to go further away in the discretization resolution as it was possible to compute simulations with 2400 particles, which we were anable to perform with only one-scale.

Bibliographie

[1] Bart Adams, Mark Pauly, Richard Keiser, and Leonidas J. Guibas. Adaptively sampled particle fluids. *ACM SIGGRAPH 2007 papers*, 2007.

[2] Keru Liu hmed Nasreldeen, Long Fan. Smooth particle hydrodynamics (sph), March 2017.

[3] P. Mocz. Create your own smoothed-particle hydrodynamics simulation (with python), September 2020.

[4] P. Mocz. Smooth particle hydrodynamics (sph)-python, September 2020.

[5] Barbara Solenthaler and Markus Gross. Two-scale particle simulation. *ACM Trans. Graph.*, 30 :81, 07 2011.