Hi everyone, I am Lixin. Together with Minchao and Zheyu, our project is to compare different transfer schemes for hybrid eulerian-lagrangian methods

Simulation Targets

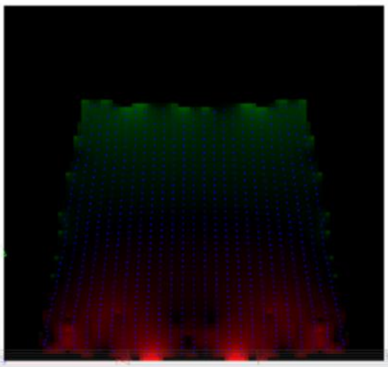
- Minimal:
  - A hybrid Eulerian-Lagrangian fluid simulation system ✓
  - Particle-in-Cell (PIC), Fluid implicit particles (FLIP) ✓
- Desired:
  - Affine PIC
- Bonus:
  - MLS-MPM
  - Extend the simulation to 3D

These are our simulation targets. By milestone, we have finished the minimal target.

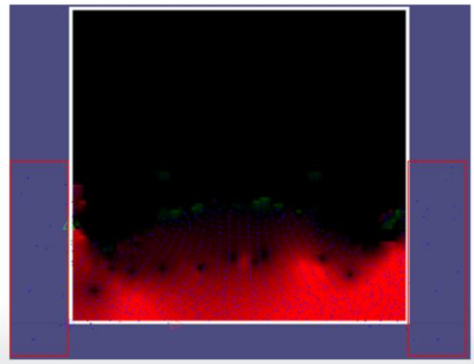
Since Milestone

- Fix existing bugs

- Velocity extrapolation



- New boundary conditions



Since then, we first fix the existing bugs by extrapolating the velocity field in the air-fluid surface as suggested by vinicius. Indeed it really helps. We also set more advanced boundary conditions so that particles won’t go out of the box.

Since Milestone

- Implement new features
  - Affine PIC ✓
  - Extend the whole pipeline to 3D ✓
  - MLS-MPM ✗

Then we implement the affine PIC and extend all three methods to 3D. Unfortunately, I failed to implement the moving least square material point method due to some unknown bugs.

2D Dam Break

Without further ado, let’s look at the simulation results. The first one is the Particle-in-Cell method. As you can see here it is very dissipative, which stops moving quite quickly. Then there is the FLIP method. It preserves momentum and enforces incompressibility much better than PIC. But it is also much noisier. Mixing the PIC and FLIP can somehow take a balance between both. Here we use a mixing coefficient of 0.95. And finally this is our implementation of affine particle-in-cell method. It preseves these vortices much better than PIC or FLIP. However, it is also not so stable now.

Angular Momentum Preservation

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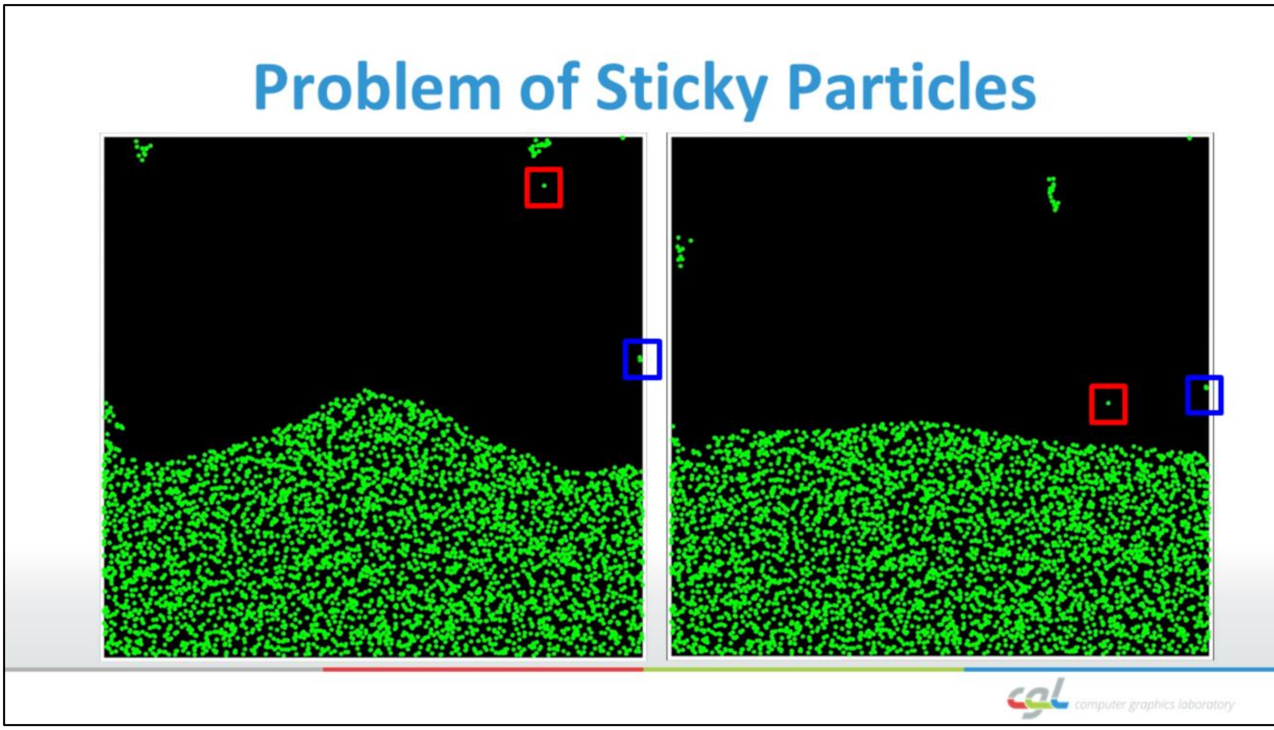
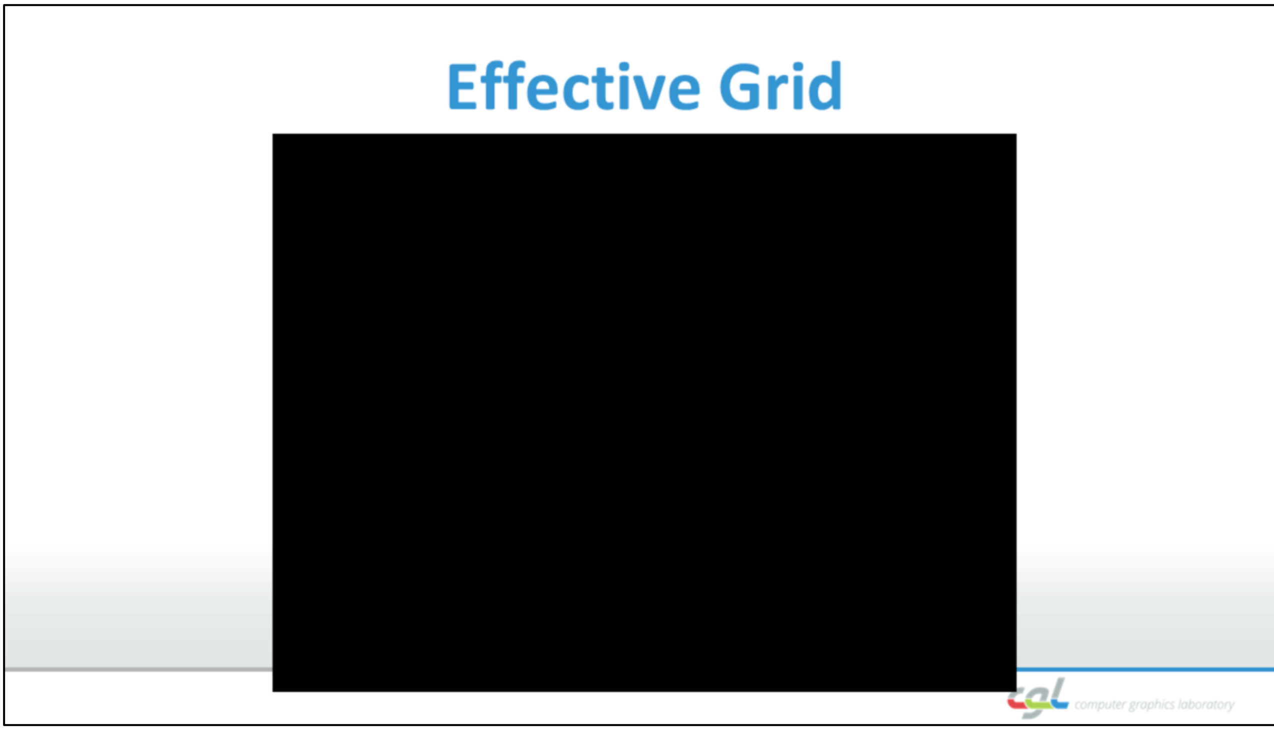
To demonstrate the superior performance of APIC on angular momentum preservation, let's look at this example. As you can see here, the PIC method stops immediately as there is too much information loss. Let's look at it again. FLIP goes on and on but in the wrong way. APIC performs significantly better than PIC or FLIP, although it also deforms a little bit.

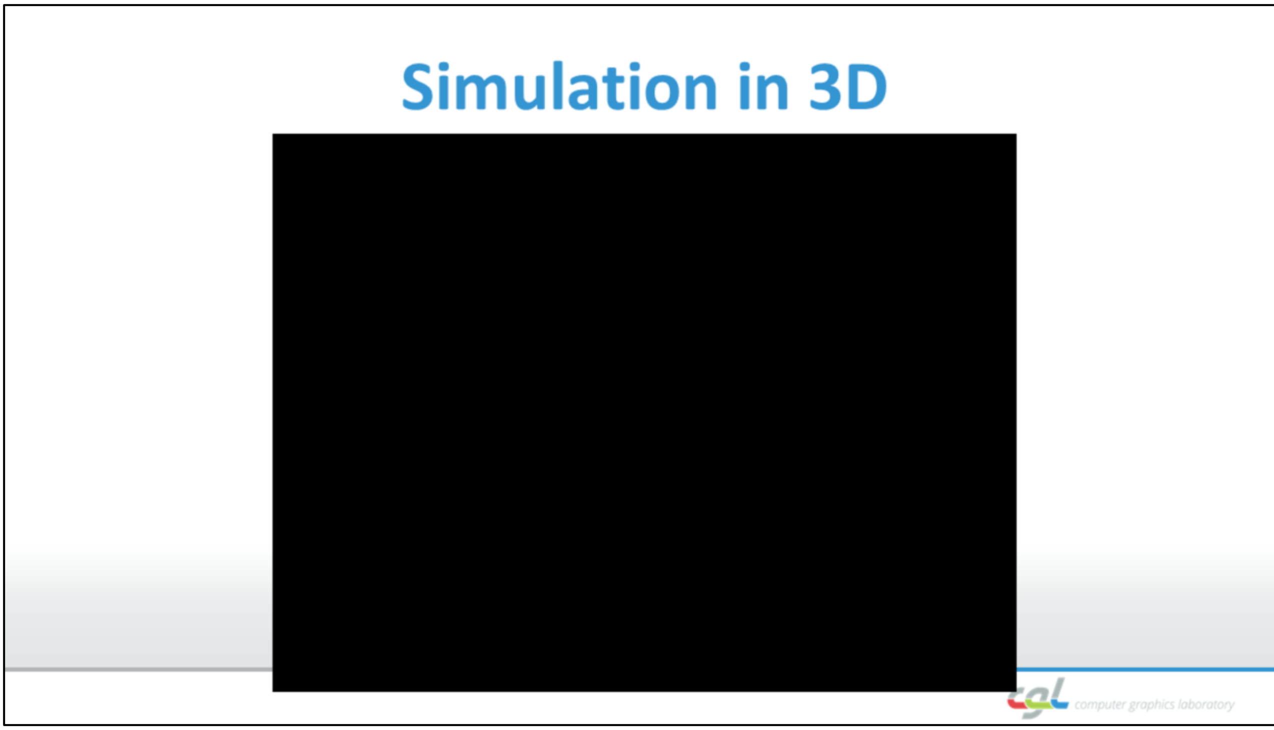


If you look closely enough, you will find there are some strange behaviors of certain particles. For example, they will stick to the upper corner of the wall. Also, when it falls alongside the wall, it falls much slower. Let's look at this PIC example. The point marked with red rectangle starts falling much higher and late than the one encircled by the blue rectangle. However, after several iterations the red point is about to join the main body of fluid, while the blue point is still going down slowly along the wall.

One reason behind this is that, the velocity is averaged over neighboring grids. The speed of point next to the solid boundary will be affected by the speed of the wall, which is zero in our case.



To fix this issue, we only take fluid grid into consideration and Ignore solid boundary when doing the grid to particle operation. This indeed help us alleviate the problem of sticky particles. However, this also makes the APIC method unstable when particles approaching the corner because this makes the velocity and affine matrix larger than before at the corner.



Here is a overview of simulation in 3D. The behaviors of different methods are similar to the ones in 2D so I won’t go over it again here. As long as the resolution and the volume of the fluid is reasonable, our simulation can run in realtime.

Summary

	PIC	FLIP	APIC
Incompressibility	-	+	-
Linear Momentum	- -	+	+
Angular Momentum	- -	+	+ +
Stability	+ +	+	-
Efficiency	+	+	-

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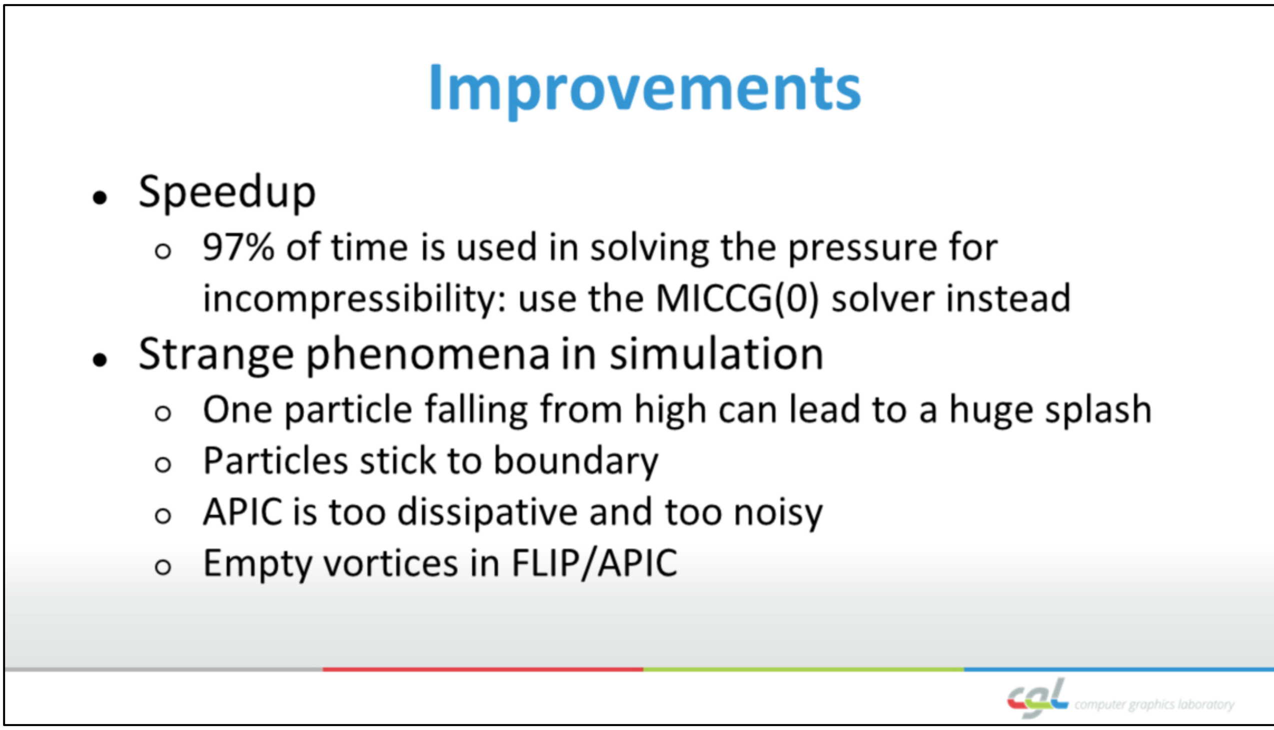
Assuming all three methods are implemented correctly, here is our comparison of different methods in various aspects.

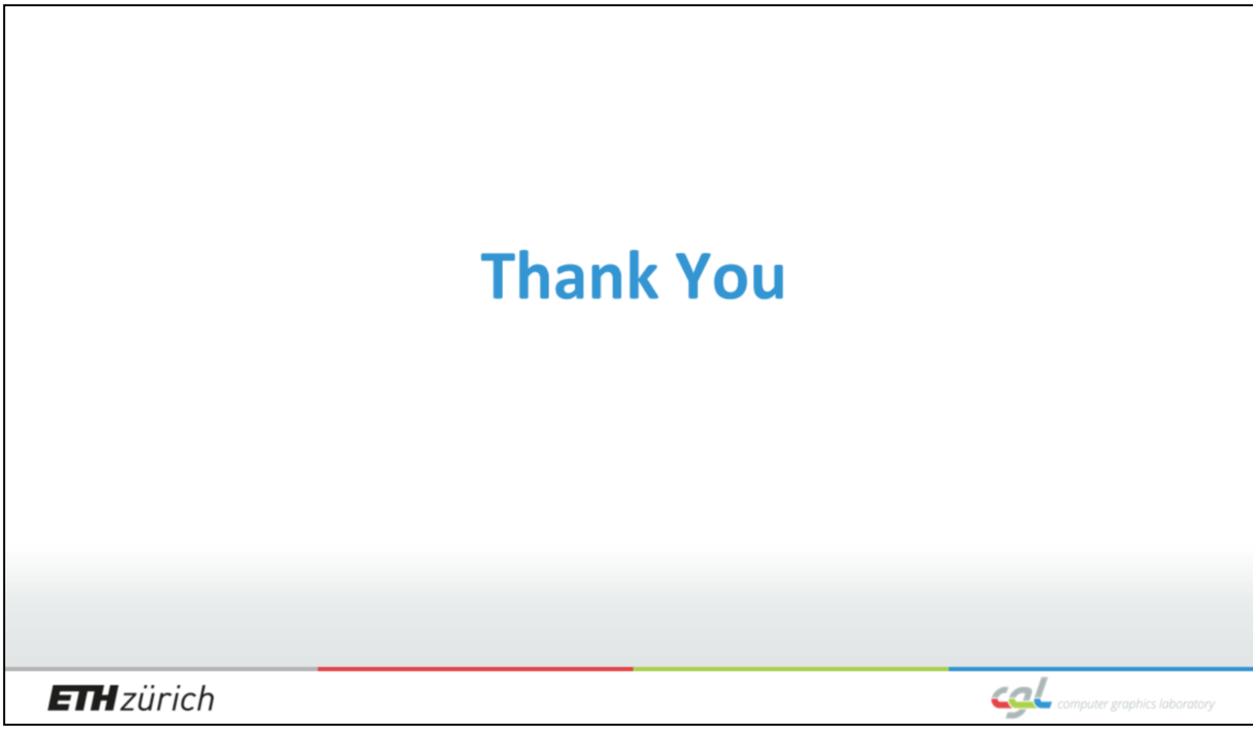


Indeed, there are quite some space for improvement. The first thing we can do is to use a better solver for pressure such as MICCG(0) to significantly reduce the runtime, as more than 97% of the time is used for solving a large linear system.
We also observe many strange phenomena. For example, one single particle can cause a huge splash on the surface. The problem of sticky particles is not fully resolved by our grid normalization. Also, we observe that our APIC is too dissipative and too noisy, which doesn’t correspond to the claims in the paper. Sometime there are also some empty vortices in FLIP or APIC, which can probably be solved via resampling the particles.

References

- Bridson & Muller-Fischer's SIGGRAPH Course Notes for Fluid Simulation
- Bridson’s Book: Fluid Simulation for Computer Graphics
- Yuanming Hu's Course on Hybrid Eulerian-Lagrangian Methods
- Jiang's Affine PIC paper
- Niall's Tutorial on MLS-MPM Fluid Simulation

Here are some references we find pretty helpful in our project.



That’s all. Thank you for listening and I am very happy to answer questions