15-464/15-664 Reference List for April 8, 2021

We began with a look at some beautiful recent research on Eulerian solvers for fluids. These papers build on the Eulerian techniques we have been studying, but utilize an interesting trick to minimize dissipation during the projection step. Recall that the projection step is where we modify pressures to make the fluid conserve mass, i.e., to make it divergence free. This step typically has resulted in loss of energy, damping out the fluid and making it less interesting. These papers use a reflection of velocities midway through each timestep to reduce this energy loss.

Zehnder, Jonas, Rahul Narain, and Bernhard Thomaszewski. "An advection-reflection solver for detail-preserving fluid simulation." *ACM Transactions on Graphics (TOG)* 37, no. 4 (2018): 85. https://jzehnder.me/publications/advectionReflection/

Narain, Rahul, Jonas Zehnder, and Bernhard Thomaszewski. "A Second-Order Advection-Reflection Solver." *Proceedings of the ACM on Computer Graphics and Interactive Techniques* 2, no. 2 (2019): 1-14. http://rahul.narain.name/ar2/

In fact, most of the research in fluids over the years has been built around trying to reduce dissipation and preserve fluid detail. This paper asks whether we can see the difference between various methods and which technique may be best in terms of perceptual accuracy. You can see the comparisons that they present to users in the associated video.

Um, Kiwon, Xiangyu Hu, and Nils Thuerey. "Perceptual evaluation of liquid simulation methods." *ACM Transactions on Graphics (TOG)* 36, no. 4 (2017): 143. https://ge.in.tum.de/publications/2017-sig-um/

We can take a look at the various fluid simulation approaches which they compare.

MP and LS methods are due to Nick Foster's Eulerian approach, which we explored over the last week, with LS indicating a level set method to smooth out and track the fluid surface. As a reminder, here is the paper we examined last Wednesday that introduced the MP / LS method.

Foster, Nick, and Dimitri Metaxas. "Realistic animation of liquids." Graphical models and image processing 58, no. 5 (1996): 471-483. http://www.cbim.rutgers.edu/dmdocuments/gmip96%20Foster.pdf

PIC and FLIP methods involve switching between grid based and particle based representations to try to combat dissipation that occurs due to using a grid for advection (although as we will see PIC just introduces more dissipation and smoothing!). These techniques are well discussed in these course notes and slides:

SIGGRAPH 2007 course: Robert Bridson and Matthias Müller-Fischer, "Fluid Simulation for Computer Animation" http://www.cs.ubc.ca/~rbridson/fluidsimulation/

In particular, take a look at this short slide deck on combatting dissipation: https://www.cs.ubc.ca/~rbridson/fluidsimulation/CombatingDissipation.ppt

The APIC method attempts to conserve affine transformations in the mapping to and from particles and is covered in this paper:

Jiang, Chenfanfu, Craig Schroeder, Andrew Selle, Joseph Teran, and Alexey Stomakhin. "The affine particle-in-cell method." *ACM Transactions on Graphics (TOG)* 34, no. 4 (2015): 51.
https://dl.acm.org/citation.cfm?id=2766996
https://vimeo.com/159438315

This website contains the APIC course project that I mentioned in class. (There may be more recent versions of it -- I did not do a complete search.)
http://graphics.stanford.edu/courses/cs348c/PA3_APIC2017/index.html

WCSPH and IISPH try to solve the problem of simulating incompressibility in SPH fluid simulations efficiently and are covered in the following papers.

Becker, Markus, and Matthias Teschner. "Weakly compressible SPH for free surface flows." In *Proceedings of the 2007 ACM SIGGRAPH/Eurographics symposium on Computer animation*, pp. 209-217. Eurographics Association, 2007. https://dl.acm.org/citation.cfm?id=1272719

Ihmsen, Markus, Jens Cornelis, Barbara Solenthaler, Christopher Horvath, and Matthias Teschner. "Implicit incompressible SPH." *IEEE Transactions on Visualization and Computer Graphics* 20, no. 3 (2014): 426-435. https://ieeexplore.ieee.org/abstract/document/6570475

For more overview + in-depth discussion of SPH, you might want to check out this Eurographics tutorial:

Koschier, Dan, Jan Bender, Barbara Solenthaler, and Matthias Teschner. "Smoothed particle hydrodynamics techniques for the physics based simulation of fluids and solids." *arXiv preprint arXiv:2009.06944* (2020).
https://arxiv.org/pdf/2009.06944.pdf
https://interactivecomputergraphics.github.io/SPH-Tutorial/