15-464/15-664 Reference List for March 25, 2020

We will begin with a look at some beautiful recent research on Eulerian solvers for fluids. These papers build on exactly 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 provide a solution.

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

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

Fluid control

Aside from making fluid more realistic, there are other things we may wish to do. For example, how do we coerce a fluid into going where we want it to go or into taking on keyframes? The go-to references for this topic are the first two, while the third shows an extension by previous 15-464 students.

Fattal, Raanan, and Dani Lischinski. "Target-driven smoke animation." In *ACM Transactions on Graphics (TOG)*, vol. 23, no. 3, pp. 441-448. ACM, 2004.

McNamara, Antoine, Adrien Treuille, Zoran Popović, and Jos Stam. "Fluid control using the adjoint method." In ACM Transactions On Graphics (TOG), vol. 23, no. 3, pp. 449-456. ACM, 2004.
http://grail.cs.washington.edu/projects/control/

Alfred Barnat, Zeyang Li, James McCann, and Nancy S. Pollard, Mid-Level Smoke Control for 2D Animation, Proceedings of Graphics Interface 2011 http://graphics.cs.cmu.edu/projects/mlsc/

Fluids Motion Capture

Some researchers have tried to use real-world images or 3D point clouds to help guide a simulation, in a form of motion capture for fluids. Here are some examples:

Wang, Huamin, Miao Liao, Qing Zhang, Ruigang Yang, and Greg Turk. "Physically guided liquid surface modeling from videos." In *ACM Transactions on Graphics (TOG)*, vol. 28, no. 3, p. 90. ACM, 2009.
http://vis.uky.edu/~gravity/Research/WaterRec/WaterRec.html

Li, Chuan, David Pickup, Thomas Saunders, Darren Cosker, David Marshall, Peter Hall, and Philip Willis. "Water surface modeling from a single viewpoint video." *Visualization and Computer Graphics, IEEE Transactions on* 19, no. 7 (2013): 1242-1251. http://www.staff.science.uu.nl/~li000042/Water.html

Gregson, James, Ivo Ihrke, Nils Thuerey, and Wolfgang Heidrich. "From Capture to Simulation-Connecting Forward and Inverse Problems in Fluids." *ACM Transactions on Graphics* 33 (2014): 11. http://www.cs.ubc.ca/labs/imager/tr/2014/FromCaptureToSimulation/#files

SIGGRAPH 2013 course

You may find this course interesting:

Nils Thuerey, Theodore Kim, Tobias Pfaff, "Turbulent Fluids," http://www.ntoken.com/course2013.html

Heightfields

Heightfields are an old and standard technique to produce water that is relatively calm (think of pond ripples or an ocean away from the shore).

Peachey, Darwyn R. "Modeling waves and surf." ACM Siggraph Computer Graphics. Vol. 20. No. 4. ACM, 1986. http://dl.acm.org/citation.cfm?id=15893

A. Fournier and W. T. Reeves. A simple model of ocean waves, SIGGRAPH 86, pages 75–84 http://dl.acm.org/citation.cfm?id=15894

Here is a good explanation of a heightfield technique:

J. O'Brien and J. Hodgins, Dynamic simulation of splashing fluids, In Computer Animation 95, pages 198–205 http://graphics.berkeley.edu/papers/Obrien-DSS-1995-04/