Multiple Interacting Fluids

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1. PROBLEM DESCRIPTION AND MOTIVATION

We propose implementing a particle level set fluid simulation system that can handle multiple fluids interacting at once, based on the 2006 SIGGRAPH paper "Multiple Interacting Liquids" [Losasso et al. 2006]. Single fluid simulation systems is a technical problem with a well established body of work proposing a variety of solutions, but multiple interacting fluids is a significantly more complex problem that must be solved in order to achieve a variety of more interesting fluid effects, such as oil on water or having bubbles rise through a volume of liquid. Multiple interacting liquids could potentially also be used to approximate rigid body in fluid simulations through the use of ultra-high viscosity liquids. In "Multiple Interacting Liquids", multiple fluids are handled by treating each fluid as its own "region", with each region being treated as its own separate particle level set, and then a novel algorithm is used to map each regional particle level set onto a more standard single-valued level set [Losasso et al. 2006]. In such a system, other phenomena such as pockets of air in liquid can simply be treated as additional fluid regions.

2. APPROACH

We plan on beginning using as our base code a 3D grid based simulator developed by Christopher Batty of Columbia University for the paper "A Fast Variational Framework for Accurate Solid-Fluid Coupling" [Batty et al. 2007], in addition to our own base code from the fluid simulation assignment in class based on the Bridson SIGGRAPH 2007 course notes [Bridson and Muller-Fischer, 2007]. The Batty base code is capable of simulating a single fluid against a solid arbitrary mesh container and includes a level set library, and our own base code is capable of simulating smoke inside of a arbitrarily defined grid volume.

For this project, we will need to extend the existing base code to support multiple fluids with different properties, allow for interaction between said multiple fluids, and implement support for multiple level sets and mapping regional level sets onto a single standard level set system. We will also have to further investigate the functionality of the level set code provided in the Batty base code and, if necessary, fill in any missing functionality that we may need.

3. TIMELINE

We propose breaking out timeline into three sections: tasks to be completed by the alpha review on April 13th, tasks to be completed by the final due date on May 7th, and extra functionality that would be interesting to implement on top of the core required functionality.

3.1 Stage 1: Alpha Review

For the minimum required functionality, we plan to implement two different fluids with different material properties interacting in the same simulation. This functionality will be completed by the Alpha review deadline of April 13th.

3.2 Stage 2: Final Requirements

For the required functionality that we will complete by the end of the project, we will implement multiple (greater than 2) fluids interacting in the same simulation. The fluids should have differing material properties and behave realistically when they interact. This functionality will be completed by the final deadline of May 7th, but should be completed earlier to allow time for the Stage 3 extra features.

3.3 Stage 3: Extra Functionality

On top of the core functionality, one extra feature we would like to support is air bubbles inside of fluid(s) by treating air bubbles as simply another fluid with a set of special material properties. Another piece of functionality we would like to examine is Maya integration; a significant portion of generating convincing fluid simulations is in simply rendering out the simulation using rendering and shading and lighting that is convincingly close to real life, which is a task better achieved through the use of an offline renderer than with the use of basic OpenGL.

4. WORK DIVISION

The two main problems to solve are representing and solving a particle-grid system with multiple fluid properties, and constructing multiple level set representations from said particle-grid system and mapping the level sets onto a single system. However, dividing the work simply based on these two problems is not a good idea since they must be done sequentially. Instead, we propose breaking each problem down into subtasks that we will then divide the work using; for example, in the particle-grid system, we will need to figure out how to advect multiple particle types simultaneously and at the same time figure out how to have multiple particles affect each other in a fashion that maintains conservation in properties that require conservation. How exactly these tasks should be split up will only become more certain as we conduct further investigation into the Batty source code and our reference papers, so at the time of this proposal, we have not yet fully developed a plan on how precisely different tasks will be divided.

5. SUMMARY

From this project, we expect to gain an understanding of how to simulate multiple fluids interacting with each other, in addition to how to extend the general fluid simulation system developed in class to support liquids and how to construct level sets. We will also gain experience in dealing with handling viscosity and other material properties in fluid simulation that were not covered in the class smoke simulation assignment.

6. REFERENCES

FRANK LOSASSO, TAMA SHINAR, ANDREW SELLE, and RONALD FEDKIW. 2006. Multiple interacting liquids. In *ACM SIGGRAPH 2006 Papers (SIGGRAPH '06)*, 812-819.

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