ThatsANiceRenderingDave

Particle Systems

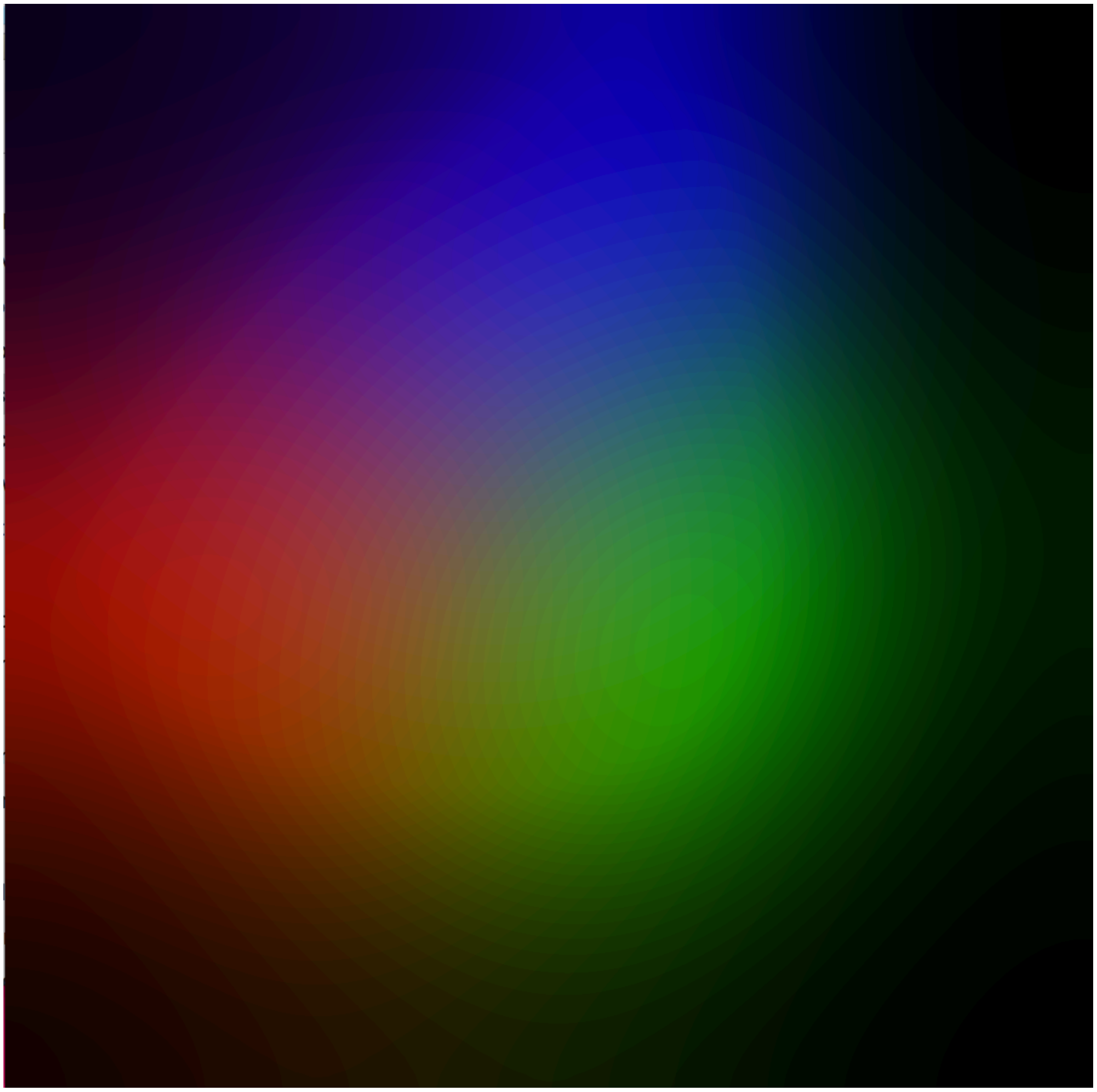
Authors: Alex Ameen, Matt Ruston, and Joshua Cristol

Overview

The focus of our project was to model multiple different systems that handle many simple particles in order to achieve interesting effects. We made a couple different systems experimenting with particles, as well as systems that move towards abstracting the particles away by using a grid to model particle density. These grided systems led us to develop a fluid simulation and a smoke system modeled in the grid. Below are all the different systems we implemented.

The Fluid System

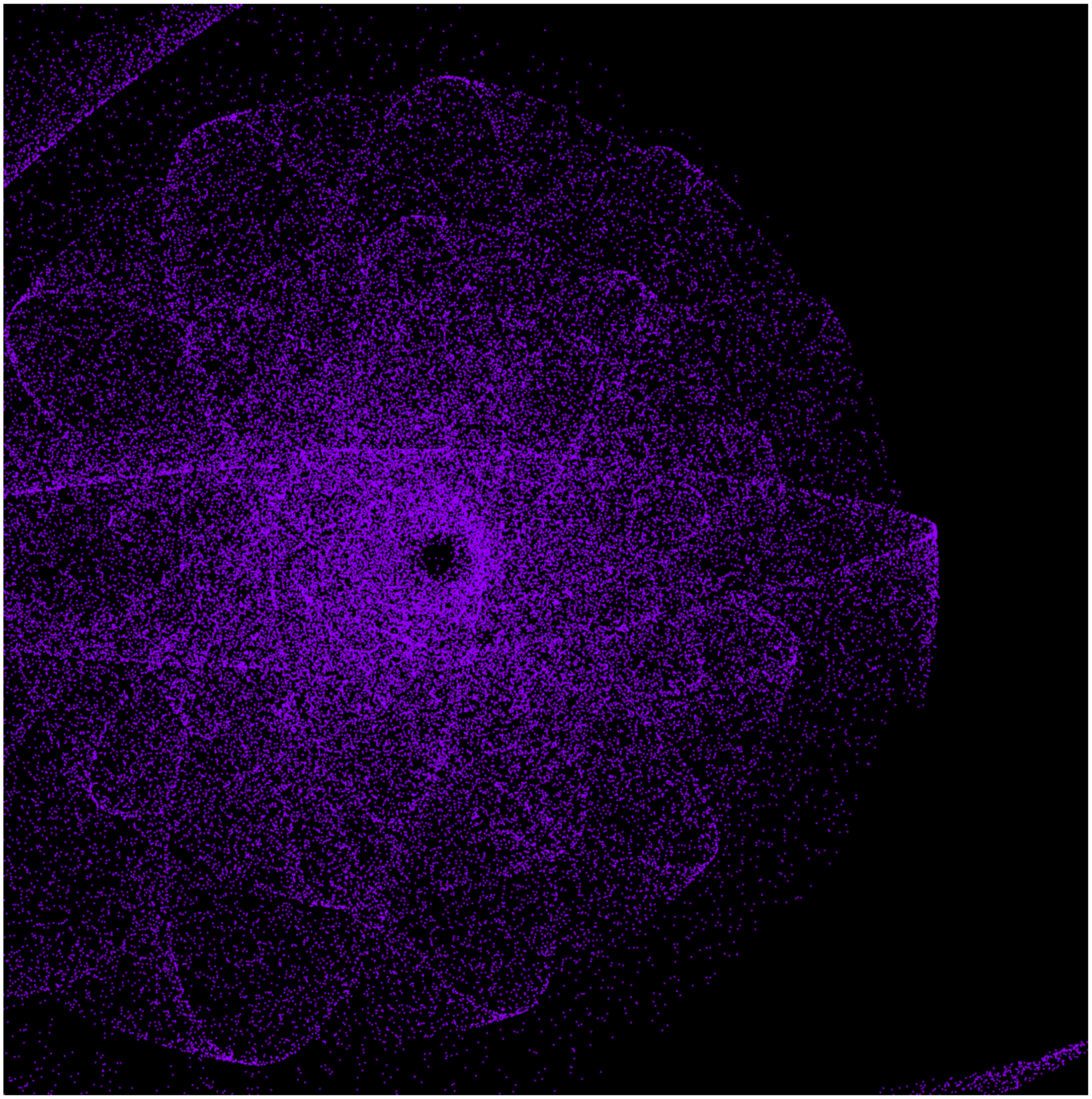
This system models simple fluid behaviors by using a grid structure to keep track of average densities and velocities in a cell's area. It is based on the Navier Stokes Equations and that paper by Jos Stam. The major steps involved in rendering out a fluid are caluclating forces which includes (advection, diffusion, and adding outside forces) and rendering out the computed fluid to the screen using a shader. The advection and diffusion code is based on Jos Stam's code which models these two processes with forward integration with velocity bounds. Without these velocity bounds, the magnitude of the average velocity of the system would increase very fast and soon the fluid would start behaving widly. Adding outside forces is easy it only requires adjusting effected velocity vectors according to Newtons law. The render is controlled by a shader that allows for mapping the velocity of the fluid at grid points and mapping the dye as it moves through the velocity field. As you can see using these simple methods you get really interesting effects in 2D.



The Space System

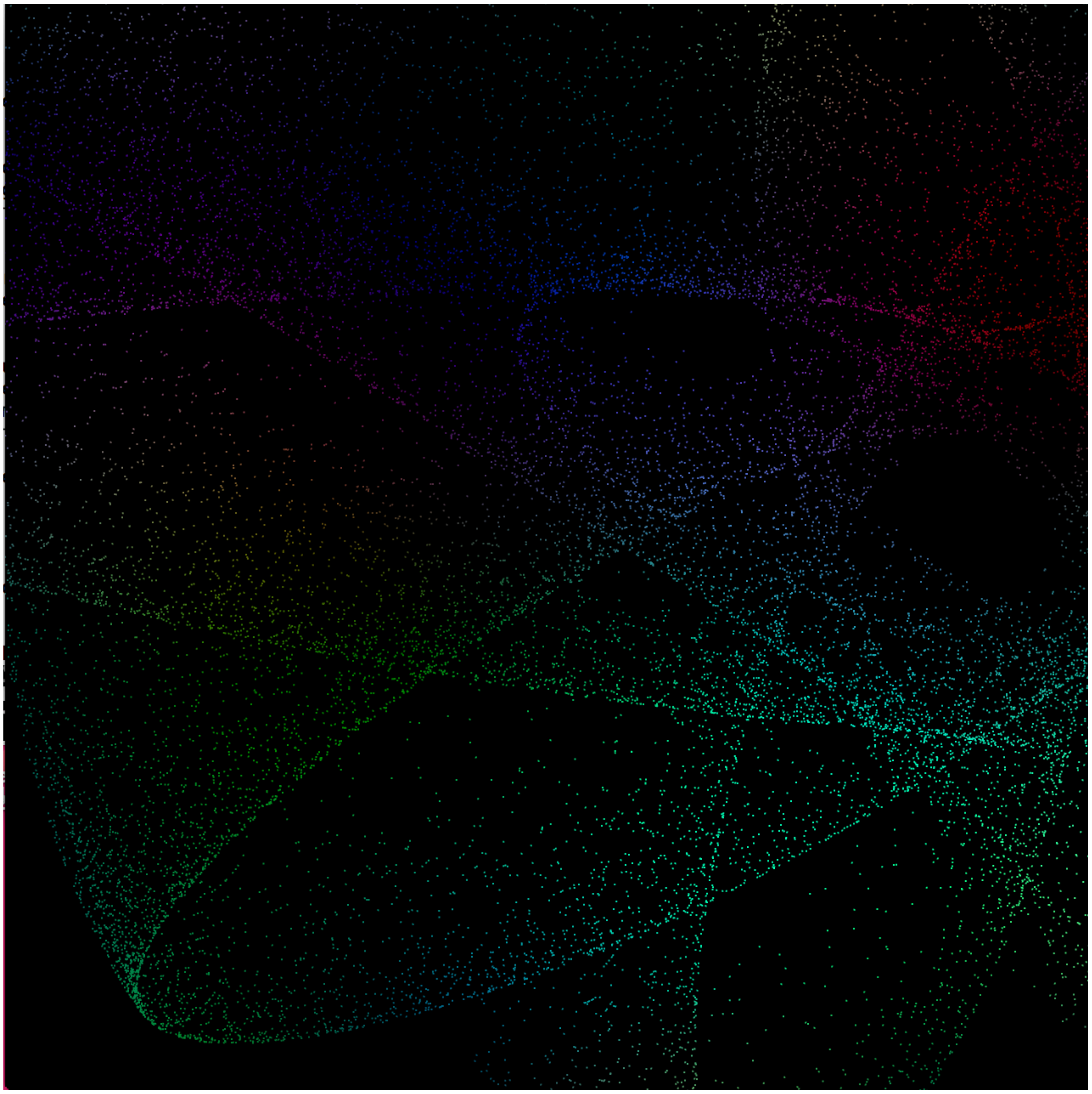
This is a simple system where 100,000 particles are put into a world, and each one is gravitationally attracted to a center point. When we first were making this system, we had a static origin point, which resulted in all the particles simply oscillating back and forth through the center. Giving the particles initial velocities would cause most of the particles to miss the center, and so they would orbit the center instead. Ultimently this effect appeared very similar to the simple oscillation. We also changed the center point to be equal to the average center of mass. This also turned out fairly uneventful, since a distribution of points around the screen end up having a center that almost stays the same as the original center point we were using.

The change that ended up making the system the most interesting was having the center point move in a circle. This causes the particles to be slung around the center, since their vector of acceleration is always changing. This produces the effect currently shown by our Space System.



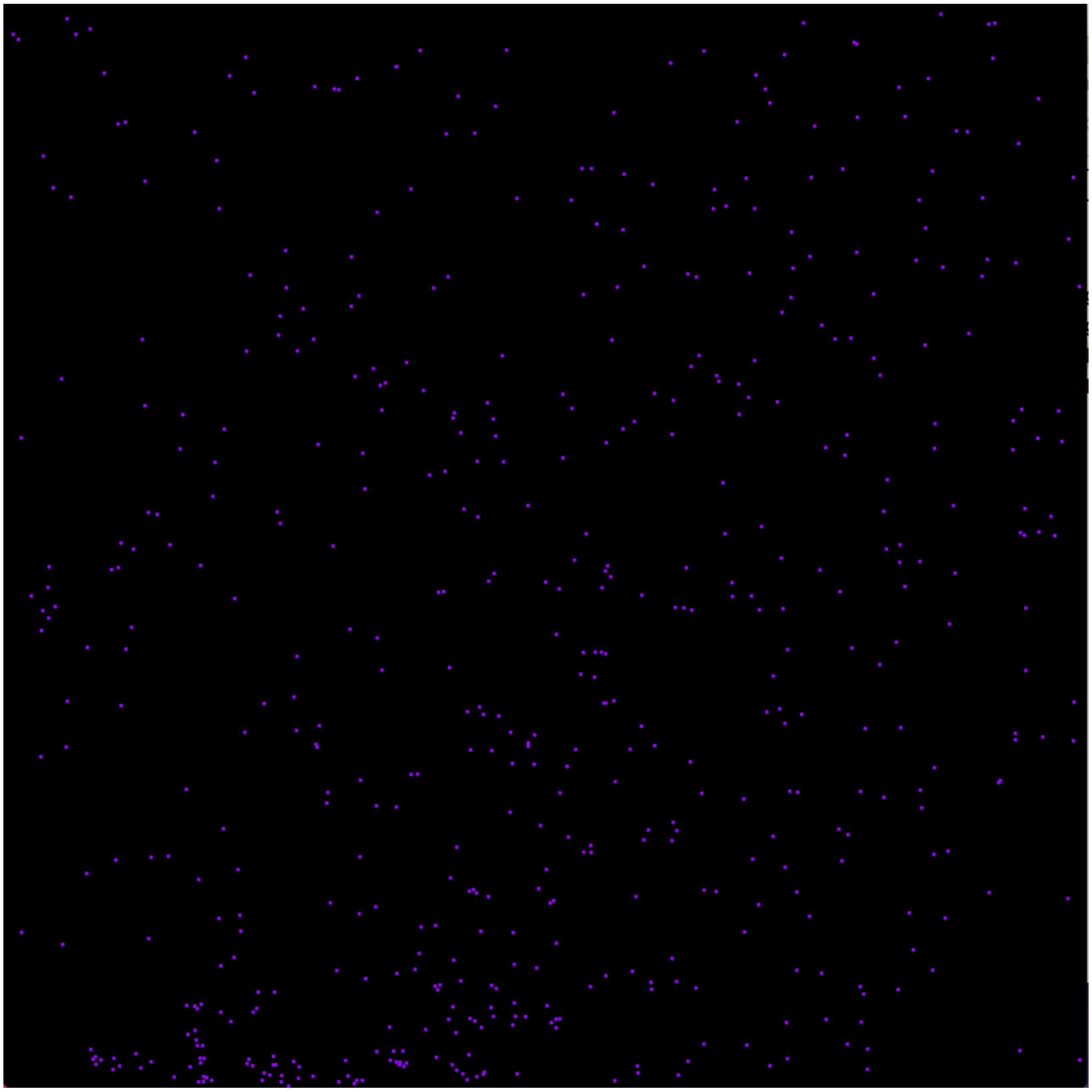
The Rainbow Space System

This system works the same as the Space System, however it uses a different shader which utilizes perlin noise to color the particles based on their location. The shader uses a noise function to generate Red, Blue, and Green color values depending on where the particle is in the xy plane of the window. This shader can be extended to almost any of our Particle Systems as an added effect.



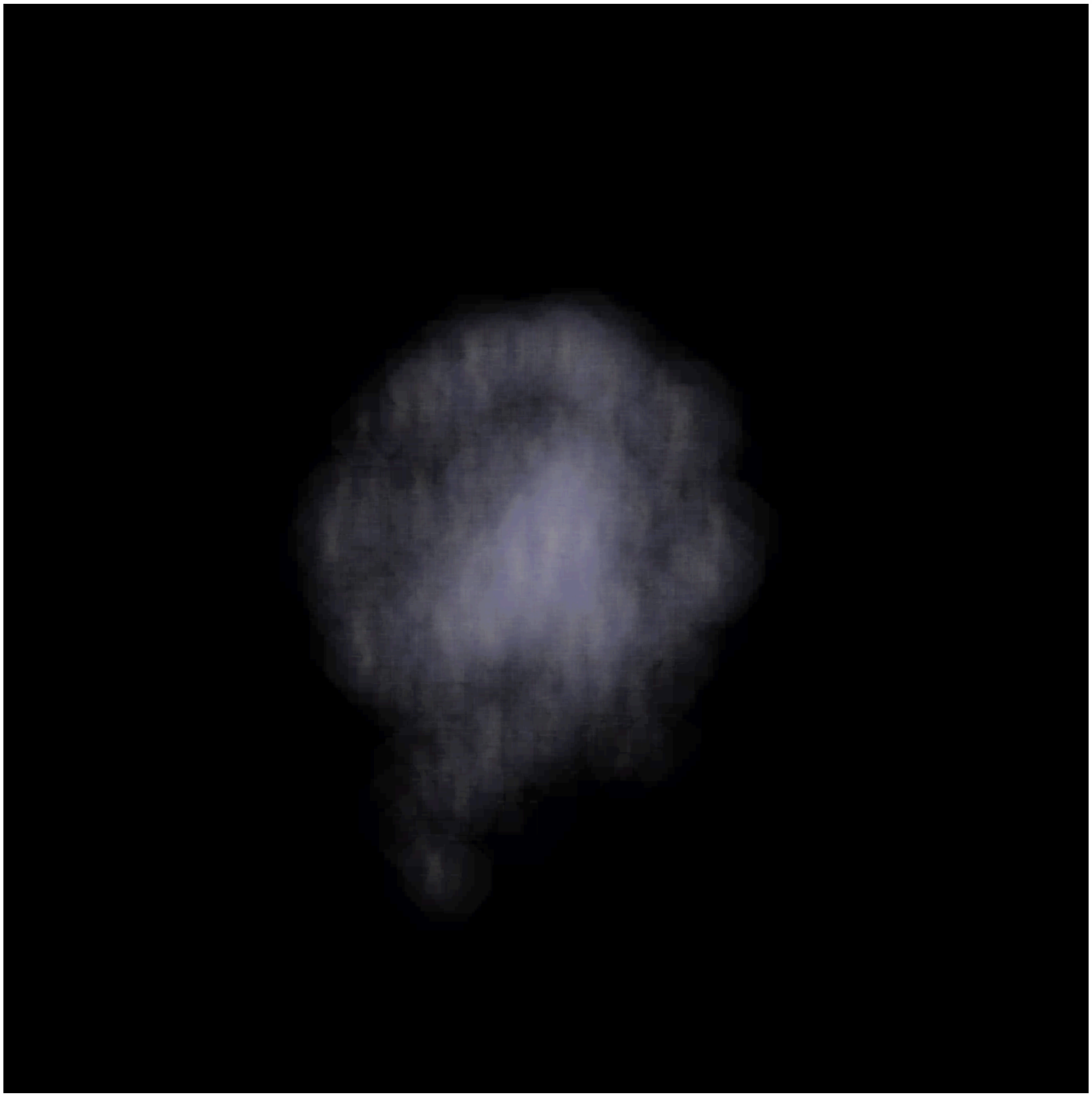
Collision and Gravity System

This system handles simple collision between particles and the boundries of the screen. To do this we use Verlet particles, which use a previous and current position in order to determine velocity. In order to determine collisions, the system will take a step, check if anything has gone out of bounds or crossed paths. To test whether a particle is colliding with another particle the collision system uses a spatial data structure to find the particles that it could be colliding with. Using this spatial data structure increases performace of detecting collisions from polynomial to near linear time. The gravity of the system is just a constant downward force on all the particles and can be adjusted with easily with input variables.



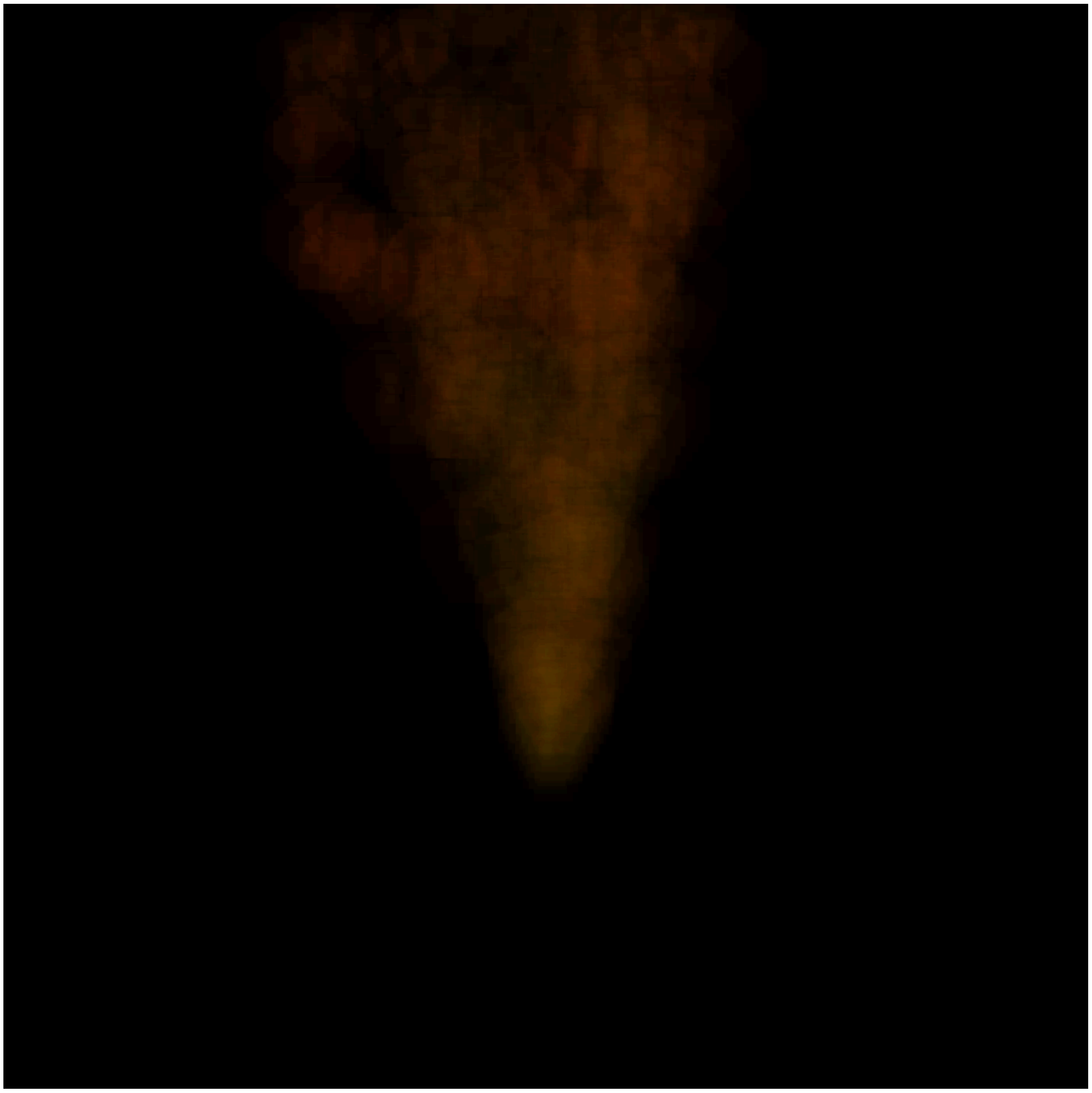
Smoke System

This system is a modification of the Space System. The particles are placed around the center of gravitation in order to keep the oscillation effect, and the movement of the center's circular path has been reduced. The largest difference is that a new shader has been applied to the particles. Now, each particle will generate a small cloud of particles. The cloud will deform slightly based on the movement of the particle. This collection of 500 particles, each producing a little cloud, collectively create a pretty nice looking smoke cloud. The system also has the option of acting as an emitter instead of a set number of particles floating around a point. This gives more of an outward movement to the system, as shown by the Fire System.



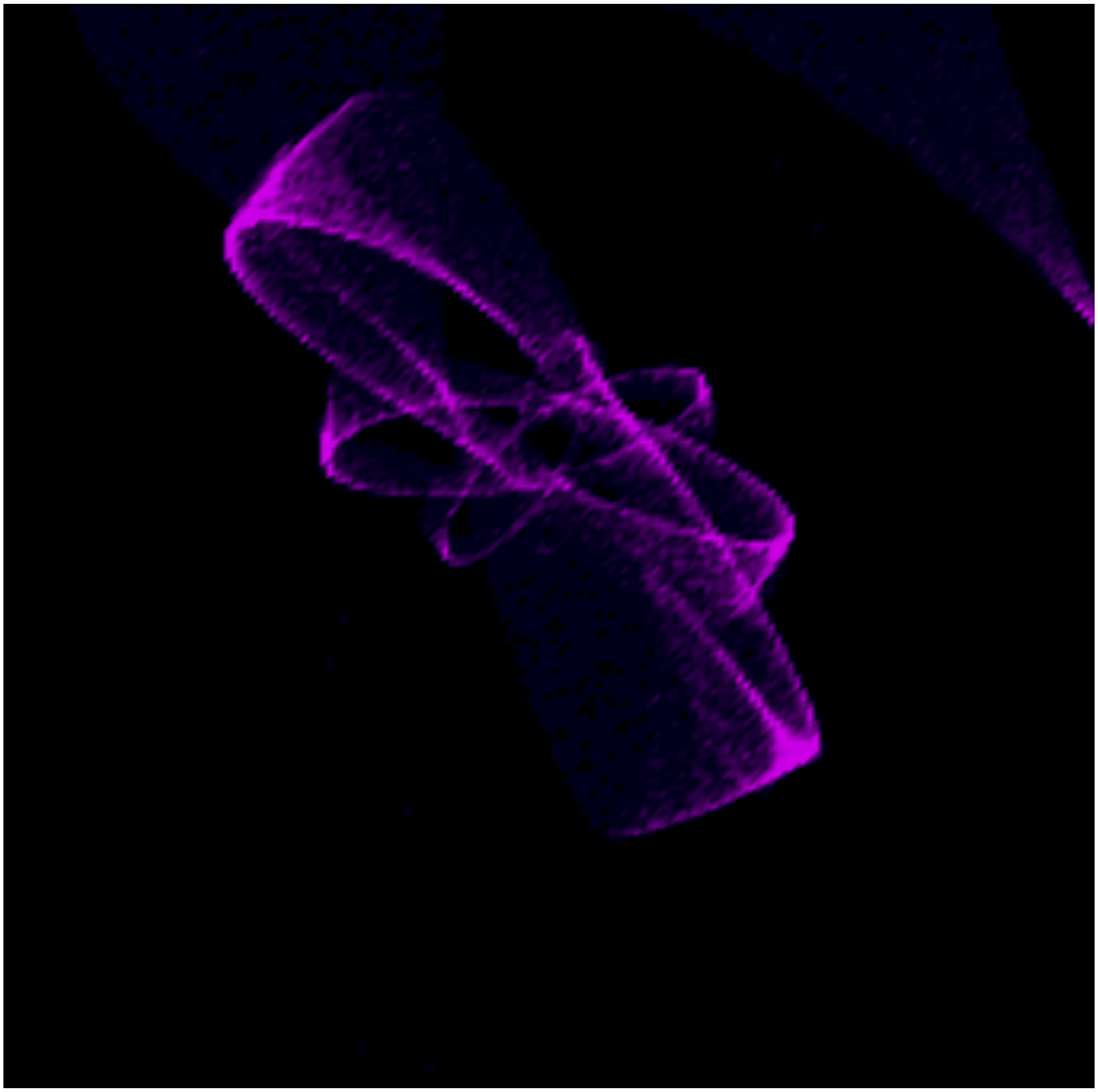
Emitted Smoke (Fire) System

This is just a version of the Smoke System where it acts as an emitter instead of a cloud of particles. To achieve a simple fire effect, the emitter only will create particles with upward velocity, with a small variation of horizontal velocity. The shader used is also the same with just a slight tweak to cause the color to be more like a fire. The color is less red the faster the particle is moving, causing more of a yellow color at the base of the fire, and more red near the top where the particles have started to slow down.



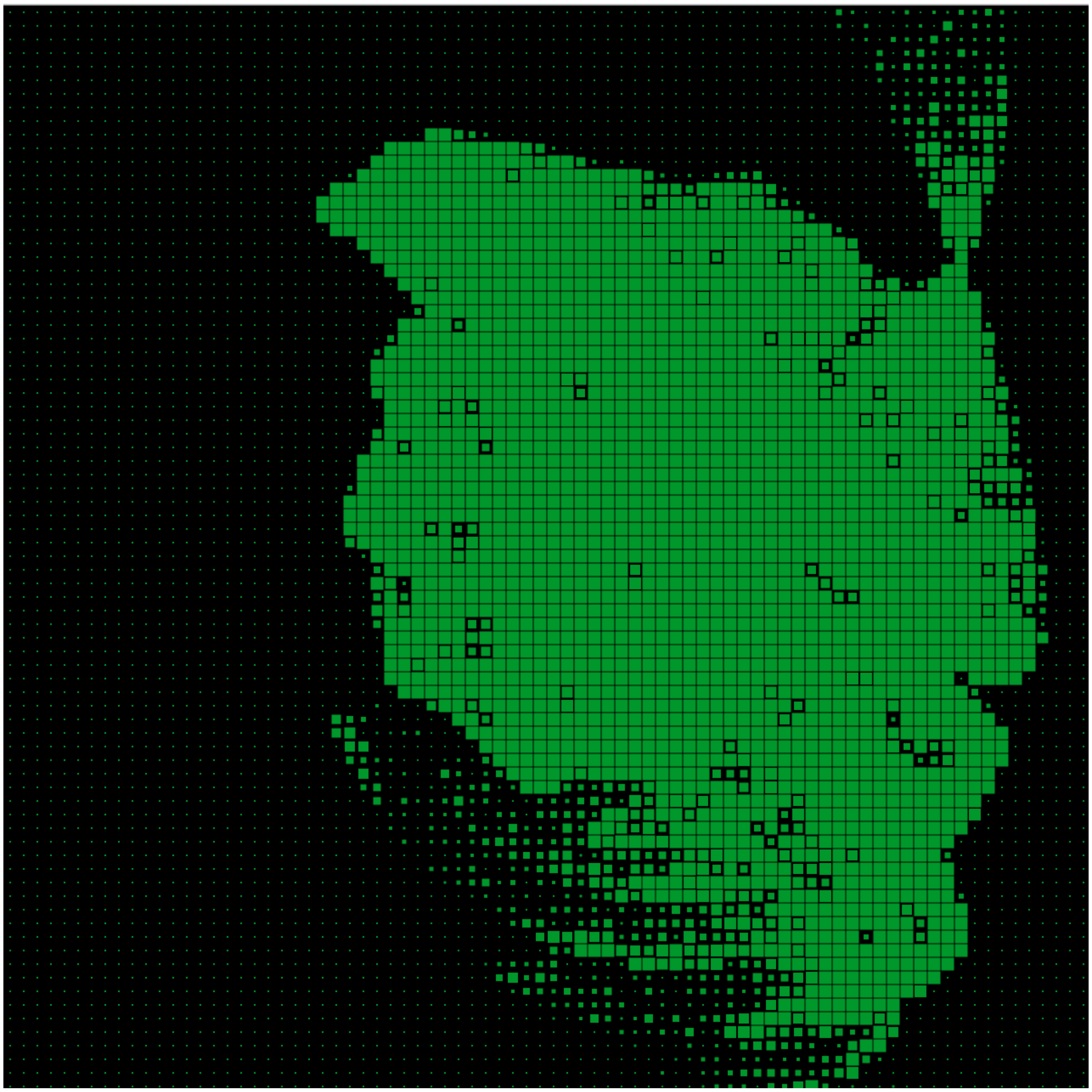
Grid System

This system acts as a layer over other systems. It divides the screen space into a grid of nodes and tracks the number of particles currently in each node as the particles move around. Since it is aware of where all the particles generally are, the shader then just has to draw squares across the screen for each node, and correctly color them based on how many particles are in each square. This allows us to run a system with many thousands of particles, but instead of having to draw each individual one, the grid just has to color its cells appropriately. This allows the system to run faster, while still being able to model all the same movement.



Pixel Grid System

Just like the Grid System, this acts as a layer over another system. The only difference between this system and the Grid System is the shader used. Instead of drawing squares across the screen, each cell in the grid is represented by a single point. That point's size represents the number of particles in that cell of the grid.



Controls

The user can switch between systems by using different numbers:

```
1. Fluid System
2. Space System
3. Rainbow Space System
4. Collision and Gravity system
5. Smoke System
6. Emitted Smoke (Fire) System
7. Grid System
8. Pixel Grid System
```

Smoke System Controls:

```
Mouse:
    Left Click: Push particles
    Right Click: Pull particles
```

Fluid System Controls:

```
Mouse:
    Left Click : Apply Force
    Right Click : add/remove density

Keys:
    R : changes active color to red
    G : changes active color to green
    B : changes active color to blue

    CTRL : swaps between adding or removing dye

    C : clears screen
    \ : displays current settings

    - : reduces diffusion
    = : increases diffusion
    [ : reduces viscocity
    ] : increases viscocity
    ; : reduces force
    ' : increases force
    . : reduces amount of dye added or removed
    / : increases amount of dye added or removed

    a : adds an emitter at the mouse position with the current dye settings
    UP : adds Vertex emitter pointed up
    DOWN : adds Vertex emitter pointed down
    LEFT : adds Vertex emitter pointed left
    RIGHT : adds Vertex emitter pointed right
```

How to build

Just like the other projects in this class, this project can be built using cmake:

```
mkdir build
cd build
cmake ..
make -j8
```

We also have helpful scripts that can be used to build and run the project.

```
./bd : builds the project
./bdr : builds and runs the project
./run : runs the built project
```

Sources

Jos Stam's paper on fluid dynamics: http://www.intpowertechcorp.com/GDC03.pdf

Tutorials looking at using verlet particles for physics: https://www.youtube.com/watch?v=3HjO_RGIjCU

Particle system implementation: https://github.com/diwi/PixelFlow

Blog with some fluid and smoke simulations: http://prideout.net/blog/?p=58

Nvidia article for fluids: https://developer.nvidia.com/gpugems/GPUGems/gpugems_ch38.html

Fluid and Smoke paper used in the fluid simulation: https://dl.acm.org/citation.cfm?id=383260

Article used to help implement the paritcle based collison system: https://dl.acm.org/citation.cfm?id=1058147