FLIP Fluids as a Bi-directional Fuel Source in a Volumetric Fluid Simulation

Nema Safvati
Blizzard Entertainment
Irvine, CA, United States
nsafvati@blizzard.com

Ashraf Ghoniem
Blizzard Entertainment
Irvine, CA, United States
aghoniem@blizzard.com

ABSTRACT

We present a fast and flexible technique for creating Pyro simulations directly from and coupled with FLIP simulations for fuel. A typical Pyro simulation involves numerous ways to generate fuel but mostly as an input exclusively into the Pyro simulation not as a coupled partner into the simulation. None of the characteristics of the fuel and specifically the reaction of the fuel consumption is considered in a traditional Pyro simulation. We strived to create this relationship in a coupled simulation. This introduced shared fuel, divergence, and velocity data. All this sharing creates a more realistic simulation with little artificial initial velocity.

CCS CONCEPTS

• **Computing methodologies** → **Physical simulation**.

KEYWORDS

FLIP, Pyro, simulation, coupling, combustion, Houdini

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Figure 1: Final Explosion from the WoW Cinematic using FLIP Fuel coupling and Oxygen Limited Combustion

1 OXYGEN LIMITED COMBUSTION SIMULATION

Oxygen-Limited Combustion is a combustion model with a more complex and physically based[Aguilera and Johansson 2019] [Nielsen et al. 2019] approach for Pyro simulations. It outputs waste which it uses together with the fuel field to determine the amount of available oxygen in a voxel. Which in turn determines how much fuel is burned. We used this combustion model with our FLIP simulations to achieve our results. This combustion model partnered well with our FLIP simulations as to help us achieve a more realistic simulation.

Using the change in temperature to modify the divergence field of a Pyro sim creates some interesting behaviors. If the temperature increases then the divergence is positive, but if it cools then the divergence value will be negative which creates a contracting effect rather than an expansion.

The flame-front field is an SDF (Signed Distance Field) that acts as a mask for where fuel burns. It expands each timestep based on the "Spread Rate" parameter set by the user, but only to areas where fuel is greater than 0 and the temperature is greater than the ignition threshold. Then when the combustion is calculated, the amount of fuel burned is scaled based on the depth. When the fuel burns, the only things that affect its velocity are divergence and buoyancy. We also added a Flame-front velocity which adds some directional motion based on the approximate motion of the flame-front.

2 COUPLING OF FLIP AND PYRO

FLIP simulations create complex liquid-like behavior that the fuel field of a Pyro sim cannot create. Gravity, drag, collisions and the internal forces of the liquid result in fuel that feels like it has mass and reacts to the combustion as it spreads through the fuel.

On each simulation step, the FLIP particles solve. Then, the "fuel" attribute from the FLIP particles is used to update the fuel and velocity fields of the Pyro simulation. Once the fuel field has been updated, the combustion solve modifies the values bases on what fuel has burned. So, on the next timestep, the FLIP particles can update their fuel attribute, affecting their mass and behavior. The particle velocity is also updated based on the Pyro velocity. The divergence from the Pyro sim is also added to the divergence field of the FLIP sim to give it a little extra explosive impact.

We hoped that by tying the two solves together we could try to mimic as close as possible something that approximates the relationship between liquid fuel and the resulting combustion.

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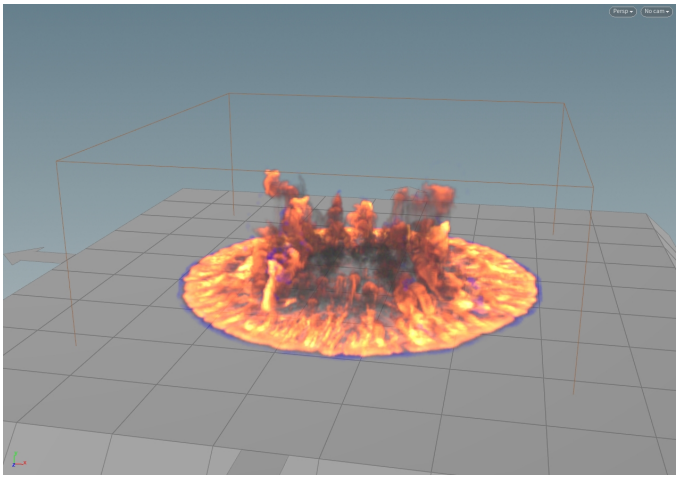

Figure 3: Example of fuel's motion driving Pyro simulation in a significant way

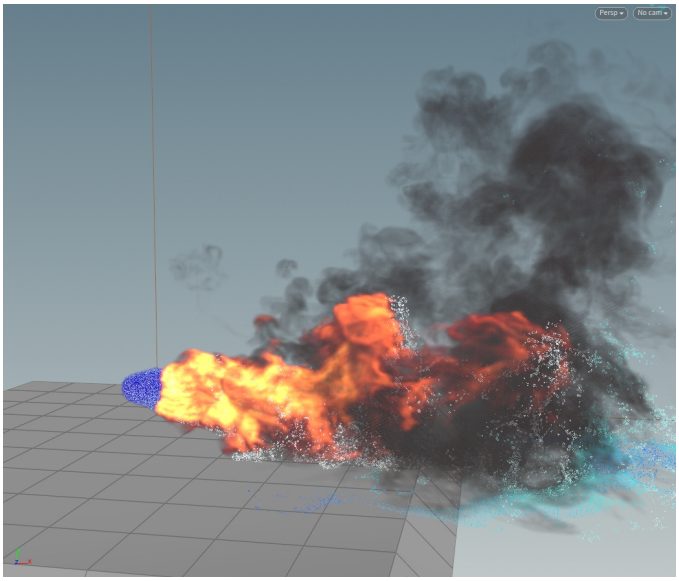

Figure 2: FLIP fuel Pyro simulation test. Trying to replicate a flame thrower

3 RESULTS AND CHALLENGES

The concept art for the magical explosions in the WoW (World of Warcraft) Beyond the Veil Cinematic, looked as if they had a volatile glowing green fuel source. Using this technique, we realized that the FLIP fuel would look interesting as a rendered element of the effect. The particles are flung around by a radial force and strong vortex force. Creating a complex source of fuel and velocity for the Pyro sim, it was rendered as an emissive volume.

Controlling the simulation can be difficult because the sharing of data creates a much more complex simulation and is more sensitive to changes than a traditional Pyro sim. Further streamlining the controls, and optimizing the operations are among the list of planned improvements.

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