Animação Computadorizada

Animação de fumaça

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Applications

- Visual smoke models have many obvious applications in the industry including special effects and interactive games[1].
- The simulation methods used to create these effects are largely based on techniques originally developed to replace scientific experiments with computer simulations[2].
- Unfortunately, controlling the details of a violent phenomenon such as an explosion remains problematic even using numerical simulations. Due to the chaotic nature of turbulent fluids, such simulations tend be both computationally expensive and unpredictable. [2]

Smoke Simulation (Pioneiros)

- Combining Physical and Visual Simulation - Creation of the Planet Jupiter for the Film "2010“ [3]
  - SIGGRAPH 86
  - Texture Images
  - Vorticity field
  - Fluid Dynamics driver
  - Particle Renderer

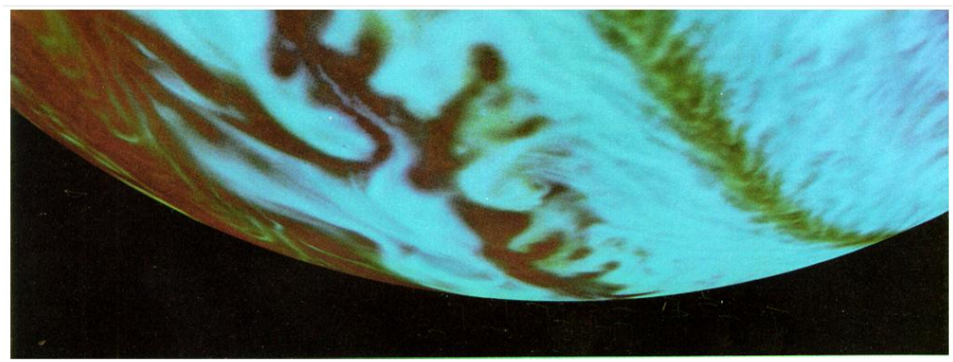
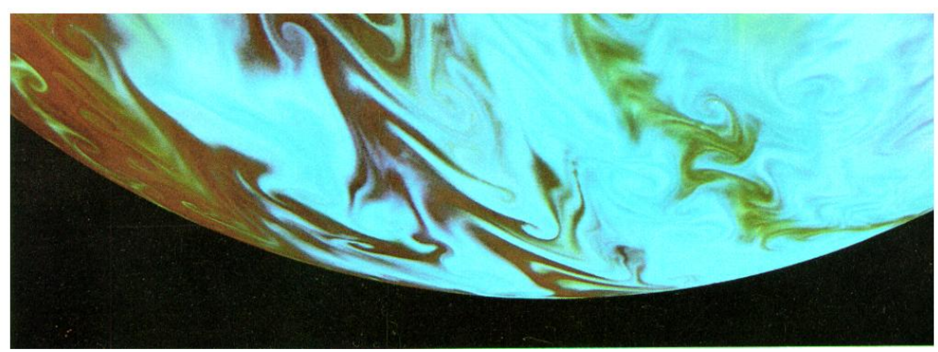
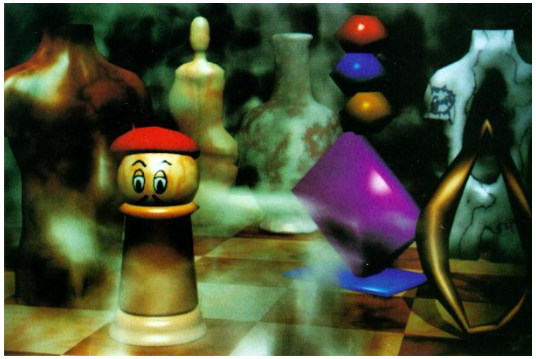
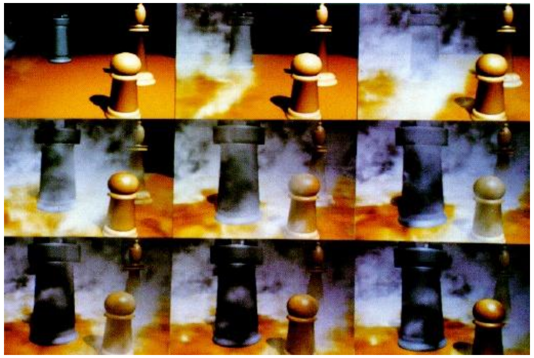


Figure 6a. Initial frame of a scene from "2010".



Smoke Simulation

- Rendering and Animation of Gaseous Phenomena by Combining Fast Volume and Scanline A-buffer Techniques [4]
- SIGGRAPH 90
  - The gases are modeled using turbulent flow based solid texturing to define their geometry and are animated based on turbulent flow simulations.

Fluid Simulation

- Fluid simulation is widely applied not only in academy, but also in the field of entertainment and film industry. [5]

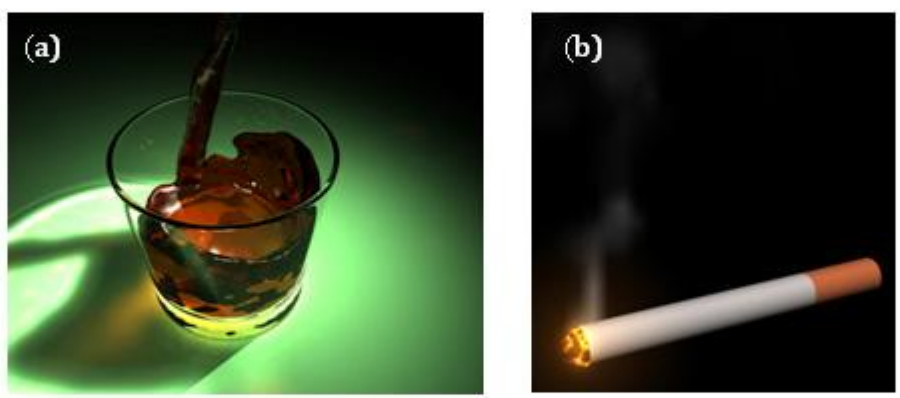
Fluid Simulation

- ***What Is a Fluid?***
  - A *fluid* is any substance that flows (in other words, a substance that can take the shape of its container) and does not resist deformation (meaning that it slides when dragged). People often use *fluid* and *liquid* interchangeable, but technically, the term fluid can refer to either a liquid or a *gas*. A gas fills its container completely, whereas a *liquid* has a distinct "free surface" whose shape does not depend on its container. [6]

Fluid Simulation

- But what about smoke? Smoke seems to behave like a gas but also appears to have a kind of surface, although perhaps not as distinct as that of a liquid. The answer is that smoke is really a combination of a gas and tiny suspended *particulates*, and the combination of these particulates is called a*erosol*. Those particulates follow the motion of the gas without necessarily influencing the motion. You can usually treat smoke as a kind of gas, where one of its properties-for example, density or composition-varies [6].

- *Fluids* have lots of freedom of motion. The motion is nonlinear and their shape and topology can change, as shown in Figure. Fluids require specialized simulation techniques: Because fluids take the shape of their container, they are always in collision with everything around them, including the fluid itself. So a collision with one part of the fluid effectively means that the whole body of fluid must respond [6].



Fluid Properties

- At a microscopic level, fluids consist of a vast number of molecules whose principle interaction is collision. But the number of molecules is so large that you cannot pragmatically deal with them as such. Instead, you have to deal with them statistically, meaning that you pretend that clusters of particles act like a special substance that behaves differently than just a collection of particles. This special treatment entails (among other things) ascribing "bulk properties" to the fluid that characterize how the fluid interacts with itself. [6]

  The most common and important properties a fluid can have include these:

  Pressure. *Pressure* refers to normal forces that apply to fluid parcels as well as the forces that fluid applies to its container and other solid objects embedded in the fluid.

  Viscosity. *Fluids* also have shear forces, which act across the fluid, distorting it. *Viscosity* is the extent to which fluid resists that distortion. Thick fluids (like syrup) have high viscosity; thin fluids (like water) have low viscosity.

  Density. *Density* expresses how much matter is in each small volume of space in the fluid.

  Temperature. *Temperature* refers to how much heat resides in a fluid parcel. Temperature itself does not directly affect how the fluid moves, but it can affect pressure and density, which in turn affect motion.

Fluid Simulation

- The fluid flow animators are interested in is governed by the famous incompressible Navier-Stokes equations, a set of partial different equations that are supposed to hold throughout the fluid [7]. They are usually written as:
- $$\frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} + \frac{1}{\rho} \nabla p = \vec{g} + \nu \nabla \cdot \nabla \vec{u}$$ [7]

$$\nabla \cdot \vec{u} = 0$$

Fluid Simulation [7]

$$\frac{\partial \vec{u}}{\partial t} + \vec{u} \cdot \nabla \vec{u} + \frac{1}{\rho} \nabla p = \vec{g} + \nu \nabla \cdot \nabla \vec{u}$$

$$\nabla \cdot \vec{u} = 0$$

- $\vec{u}$ is used in fluid mechanics for the velocity of the fluid. Three components of 3D velocity (u, v, w).
- ρ stands for the density of the fluid. For water, this is roughly 1000kg/m3 and for air this is roughly 1.3kg/m3, a ratio of about 700:1.
- p stands for “pressure”, the force per unit area that the fluid exerts on anything.
- $\vec{g}$ is the familiar acceleration due to gravity, usually.
- ν is technically called the “kinematic viscosity”. It measures how viscous the fluid is. Fluids like molasses have high viscosity, and fluids like alcohol have low viscosity: it measures how much the fluid resists deforming while it flows (or more intuitively, how difficult it is to stir).

Navier-Stokes equations

- To solve these equations numerically, several discretization schemes have been proposed. Most applications in Engineering base on either finite elements (FEM) or finite difference (FDM) / finite volume (FVM) discretizations. Finite difference methods operate on structured grids, while finite element methods evaluate base functions on irregular meshes [2].

Representations and Coordinate Systems

- The fluids can are modeled in at least two ways: as a field, or as a collection of interacting particles. Both views are useful, and you often switch between them and combine them[6].

Different Types of Fluids – Smoke

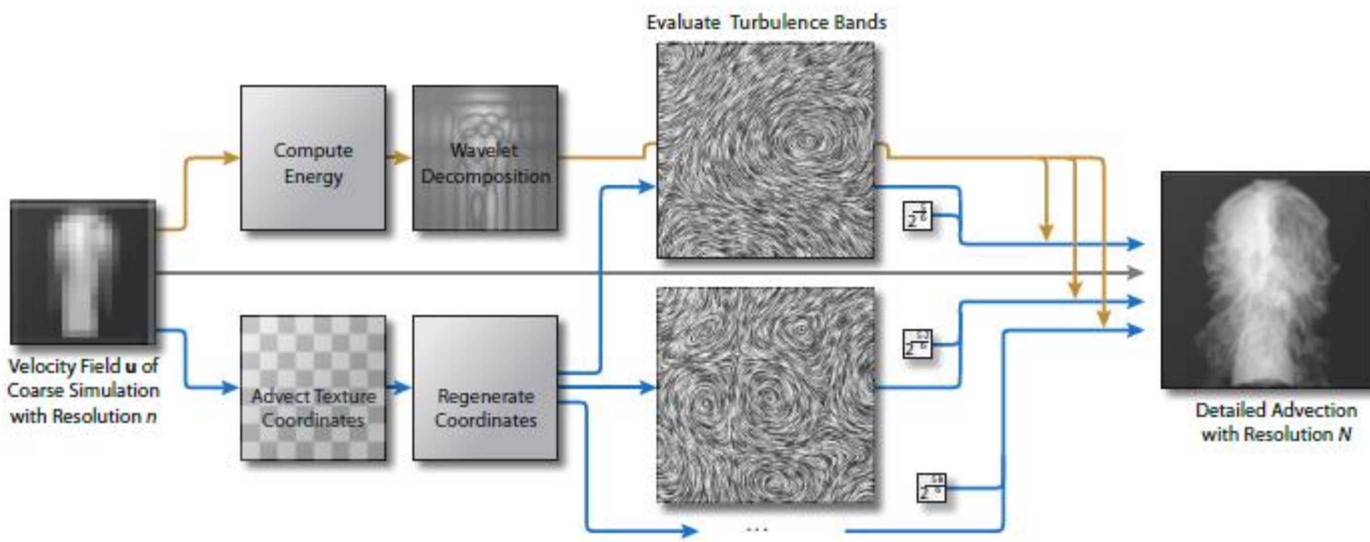
- The fluid in this case is the air in which the smoke particles are suspended;
- Two extra fluid variables: the temperature T of the air and the concentration s of smoke particles;
- Temperature changes cause the air to slightly expand or contract, causing a change in density, and the mass of the smoke particles also effectively increases the density.

Smoke Simulation

- Smoke simulation is one of the interesting topics in computer animation and it usually involves turbulence generation. Efficient generation of realistic turbulent flows becomes one of the challenges in smoke simulation. Vortex particle method, which is a hybrid method that combines grid-based and particle-based approaches, is often used for generating turbulent details [5].

Adding Turbulent Detail

- Approaches for modeling turbulent effects:
  - Wavelet Turbulence is a very practical approach that outlines a practical way to apply small scale detail for coarse fluid simulations [2];

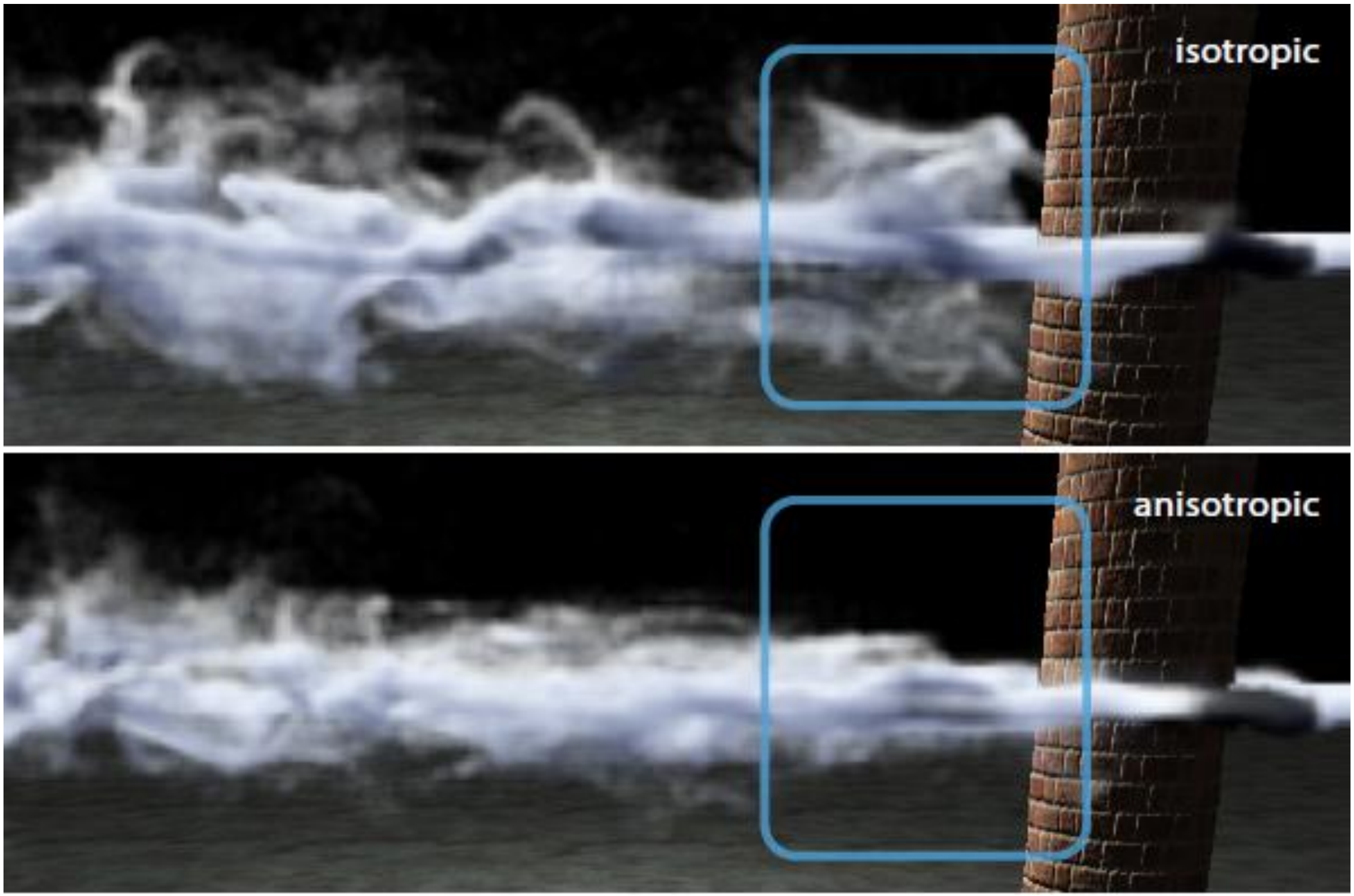


Wavelet Turbulence

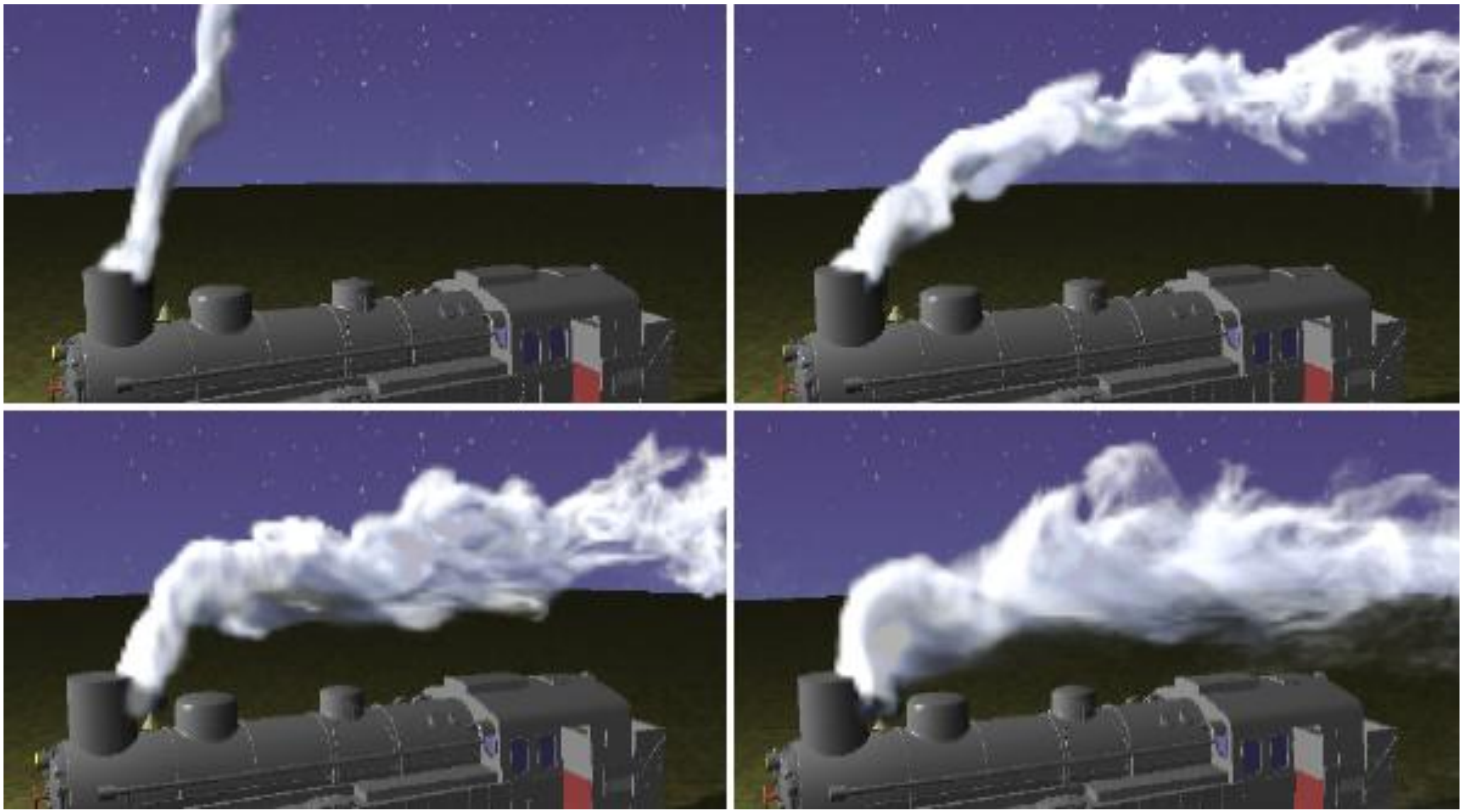
- Wavelet turbulence synthesized a 720x576x576 grid from a 80x64x64 grid. Each frame took less than two minutes on an eight core workstation [2].

Wavelet Turbulence

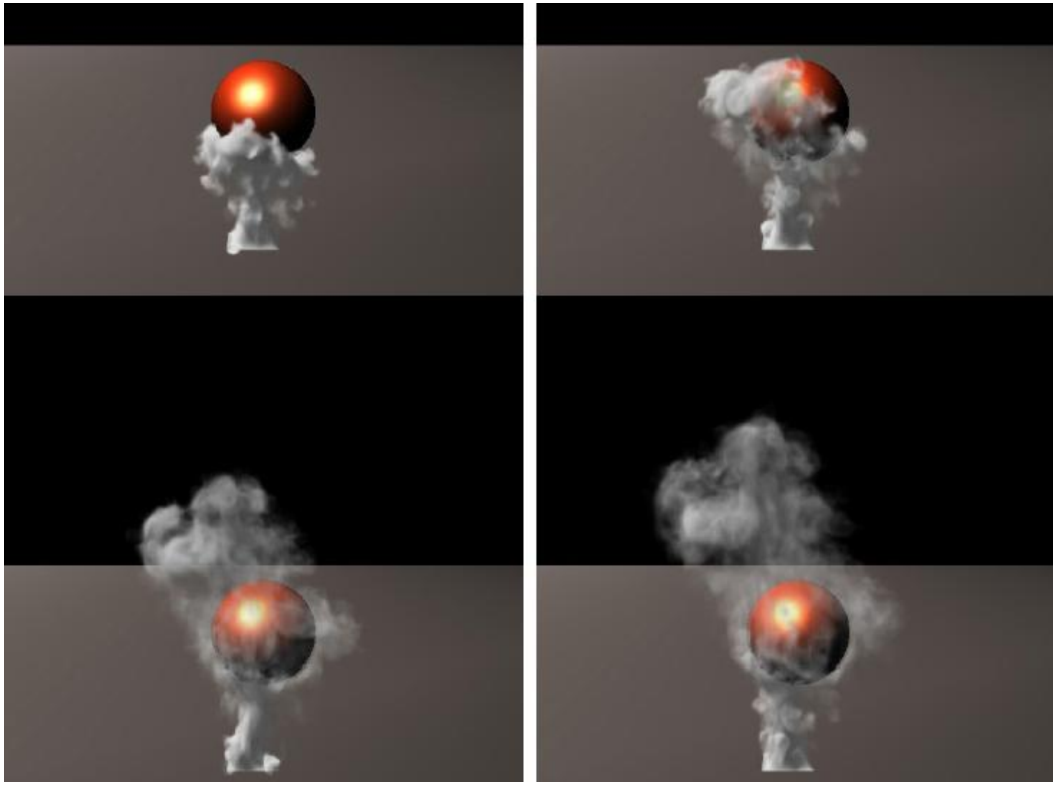
Anisotropic Turbulence Modeling



Anisotropic Turbulence [2]



An Efficient Adaptive Vortex Particle Method for Real-Time Smoke Simulation [5]



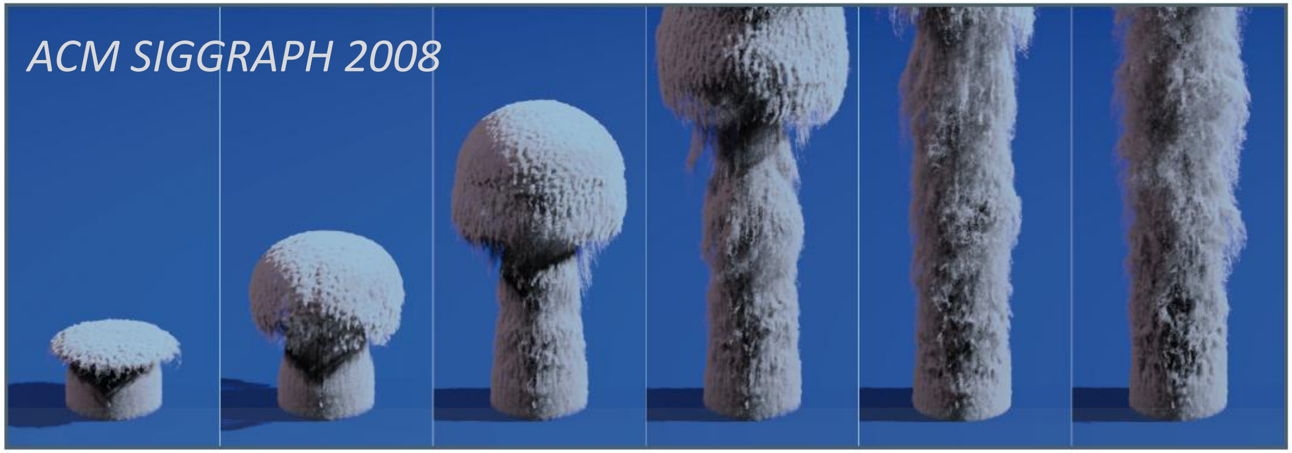
An Efficient Adaptive Vortex Particle Method for Real-Time Smoke Simulation [5]

- *In this approach, the spatial adaptive vorticity confinement force varies with helicity, leading to the fact that the grid-based simulation driven by the vortex particle is now based on the velocity field. Furthermore, we introduce an adaptive vortex particle approach to improve the computational efficiency of the simulation by making the influencing region adapt with the velocity and eliminating those particles with zero velocity in the vorticity forcing method. A parallel smoke simulator integrating our approaches has been implemented using GPUs with CUDA.*

Fire and smoke simulation using Maya fluids

- https://www.youtube.com/watch?v=rg9HS48lmgc&list=UUUwxFfkPJkUHXOhfu4u0Tvg

Smoke Simulation – Blender [8]



- Blender's new smoke simulation is based on the paper 'Wavelet Turbulence for Fluid Simulation' and associated sample code.
- It has been implemented in Blender by Daniel Genrich and Miika Hamalainen.
- The simulator uses a volumetric fluid-based model, with the end results output as voxel grids. This voxel data is visualized interactively in Blender's 3D view using custom OpenGL shading, and can be rendered using the Voxel Data texture. Blender's **smoke simulation** wraps Voxels around existing Particles. It requires a particle-emitting object and a 'domain' object within which smoke is rendered.

Lagrangian Vortex Sheets for Animating Fluids [9]

- Buoyant turbulent smoke plumes with a sharp smoke-air interface, such as volcanic plumes, are notoriously hard to simulate. The surface clearly shows small-scale turbulent structures which are costly to resolve. In addition, the turbulence on set is directly visible at the interface, and is not captured by commonly used turbulence models.
- Employs a triangle mesh as a high resolution surface representation combined with a coarse Eulerian solver. On the mesh, we solve the interfacial vortex sheet equations, which allows us to accurately simulate buoyancy induced turbulence. For complex boundary conditions we propose an orthogonal turbulence model that handles vortices caused by obstacle interaction. In addition, we demonstrate a re-sampling scheme to remove surfaces that are hidden inside the bulk volume. In this way we are able to achieve highly detailed simulations of turbulent plumes efficiently.

- http://www.youtube.com/watch?v=B5CldT0chHk

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