



Physics and Fluid Simulations in Real Time

CCI300
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Some demonstrations will have flashing lights and patterns

Abstract

- What are the common uses of real time physics?
- How is it done?

$$\vec{F} = m\vec{a}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\frac{d\vec{v}}{dt} = \frac{\vec{F}}{m}$$

$$\frac{\vec{F}}{m}$$

$$\frac{d\vec{v}}{dt} = \frac{\vec{F}_n}{m} + \frac{\mu}{m} \vec{F}_n + \frac{\vec{F}_{ext}}{m}$$

Newton's Second Law, formula for calculating acceleration, formula for momentum, the force term to describe momentum, the formula for describing rigid body objects with momentum

$$\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} = \frac{-\nabla p}{\rho} + \frac{\mu}{\rho} \nabla^2 \vec{v} + \frac{\vec{f}_{ext}}{\rho}$$

$$\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} \equiv \frac{D\vec{v}}{Dt}$$

The Navier-Stokes equation describes velocity change with force, the Lagrangian derivative the heart of fluid motion.



Abstract

- What are the different types of physics in game engines?
 - Collision Physics
 - Particle Physics
 - Rigid Body Physics
 - Soft Body Physics
 - Fluid Physics

History of Physic Effects in Entertainment

- Physics is a pervasive aspect of life
- One of the early attempts to use a fluid effect was *The Ten Commandments* in 1956.
- Was created using practical effects.
- By mimicking real life physics they were capable of creating the illusion



Image: *The Ten Commandments* 1956

History of Physic Effects in Entertainment

- The first video game to ever use a form of physics was *Tennis for Two* in 1958
- Used circuitry to simulate physical effects such as gravity and wind resistance

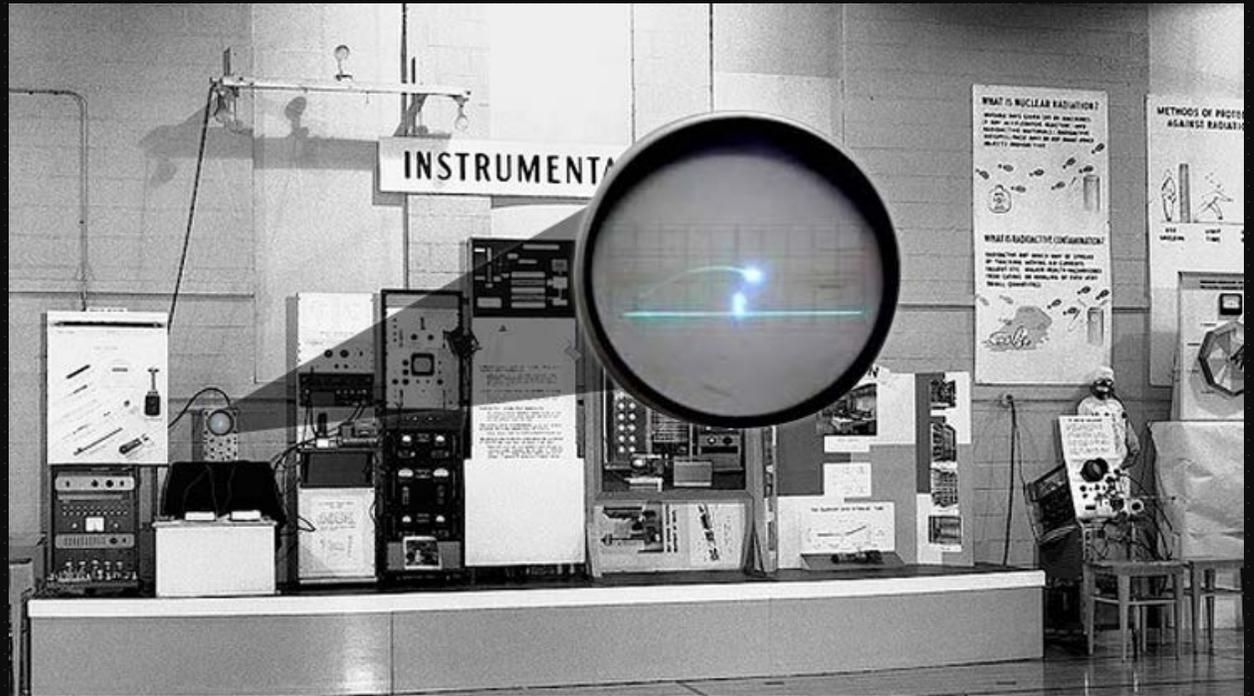


Image: *Tennis for Two*, Forever Computing

History of Physic Effects in Entertainment

- *Pong* was released by Atari as an arcade game in 1972.
- It used rudimentary collision physics
- Every collision would cause the ball to be treated as a new object. The new ball would be given a new constant acceleration emulating the ball bouncing



Image: Pong Arcade System, Pong Museum

History of Physic Effects in Entertainment

- First film to have simulated fluid was *Antz* (1998)
- Used liquid simulation entirely in computer
- Simulation takes weeks per shot using CPU

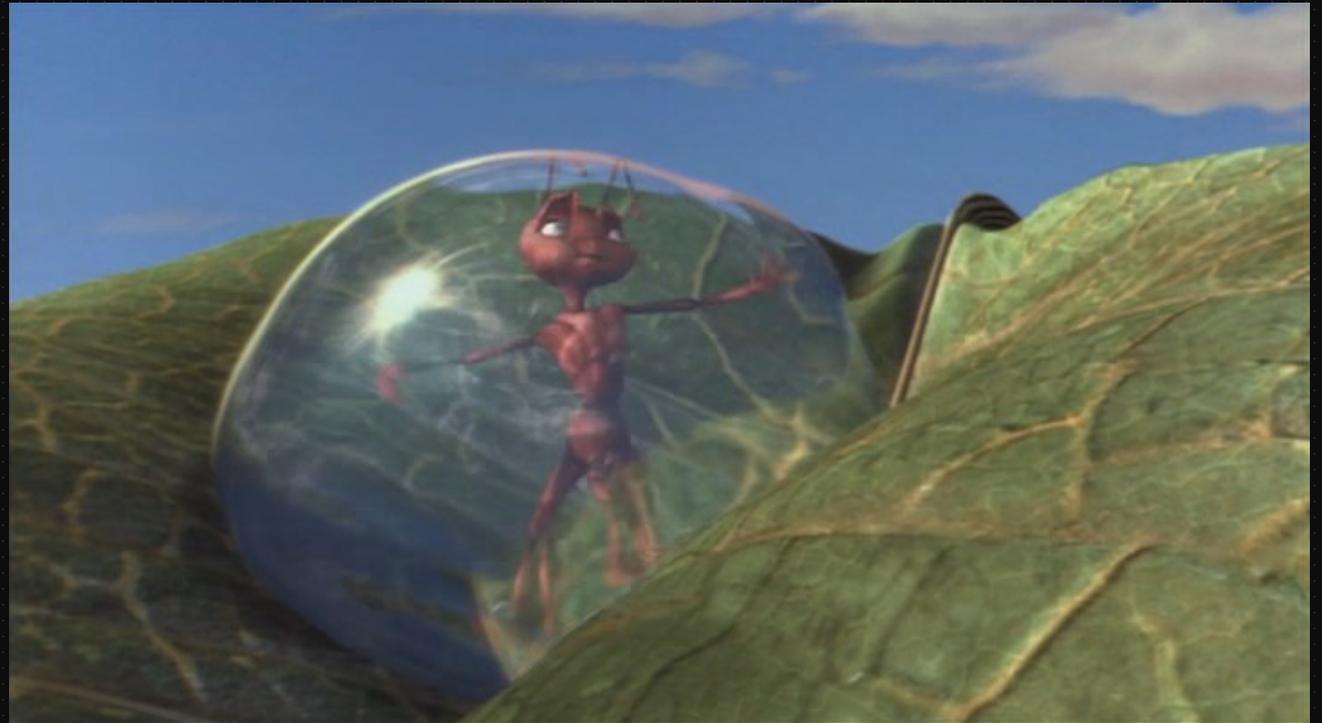


Image: *Antz* 1998

Real Time Fluid Simulation

- *Day After Tomorrow* (2004), had a city wide fluid simulation
- What took Digital Domain and Tweak Films hours to create, can now be done on a single computer using a real time physics simulation.



Particle Physics

- Particles have position, mass and velocity.
- Sprites are attached to each particle
- Can be affected by acceleration and turbulence limited to the particle system.
- Systems such as Global Vector Field in UE4 that simulate a global field within a volume.
- Used for effects such as fire, sparks, clouds and smoke.



Image: Epic Games Content example particles

Collision Physics

- Made of convex collisions
- Detects collisions between multiple actors
- Used for hitboxes, to trigger overlap events, to block actors from moving through them and determine point of collision.

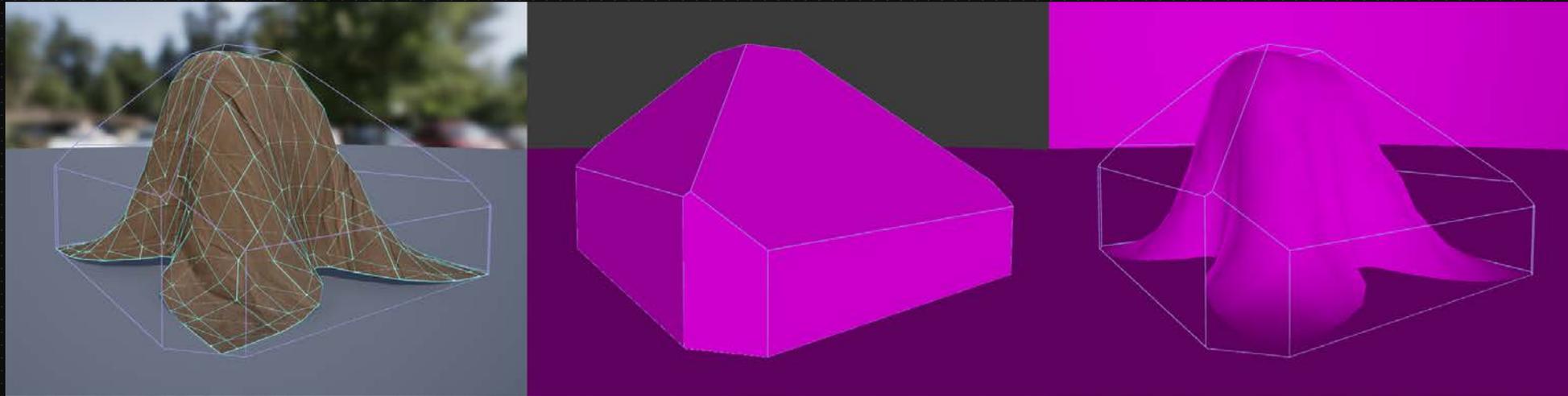


Image: Lit model from The Barn, Player Collision, Visibility Collision

Rigid Body Physics

- Physics of a non-deforming mesh
- If you add the property of shape to a particle you have a rigid body
- It relies upon mesh collision
- Creates the illusion of hard body physics such as walls, doors and trees.

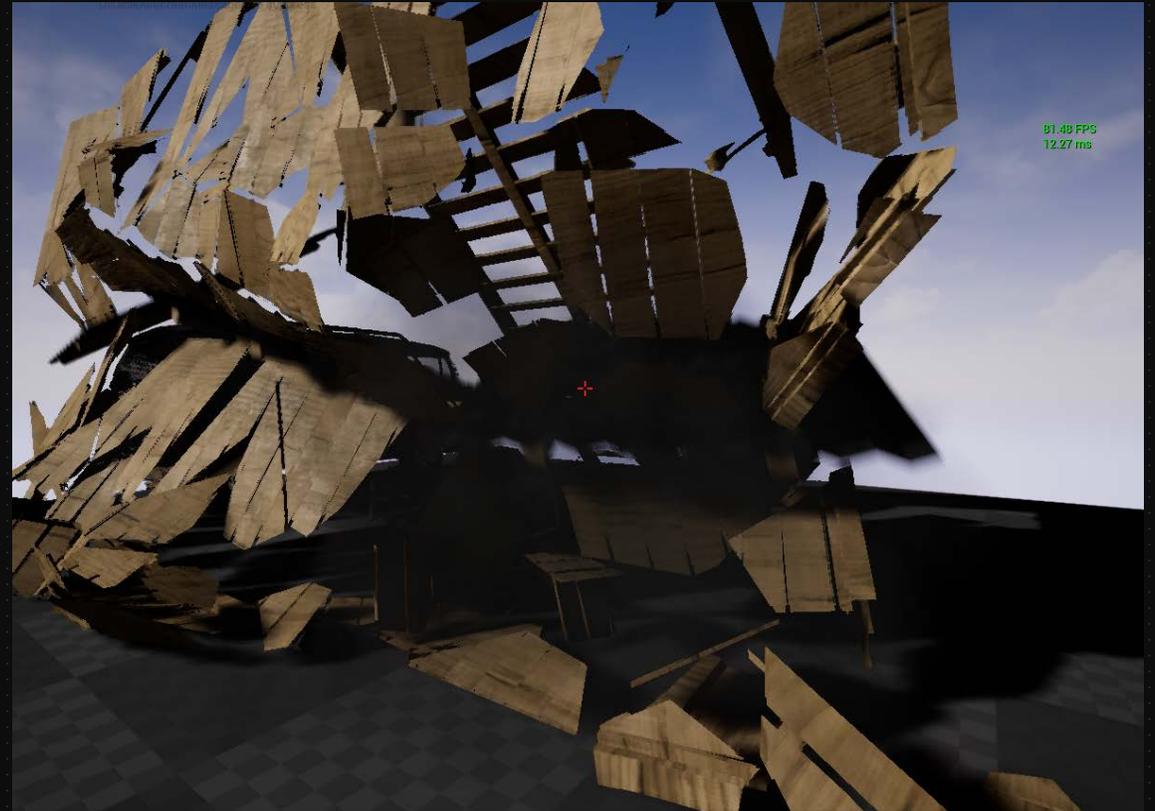


Image: Destructible rigid body mesh in The Barn

Soft Body Physics

- Physics of a deformable mesh.
- Use bounding volumes for vertices
- The shape of the soft body can change due to force
- Creates the illusions of soft body elements such as cloth, hair and deformable mesh in real time.



Image: BeamNG.drive Demo

Fluid Physics

- Real-time fluid simulation, fluids can be liquids like water or gaseous substances like smoke.
- Two main ways of simulating fluids: Field Based (Eulerian view) or Particle Based (Langragian view)
- Creates the illusion of fluids and fluid interaction in real time.

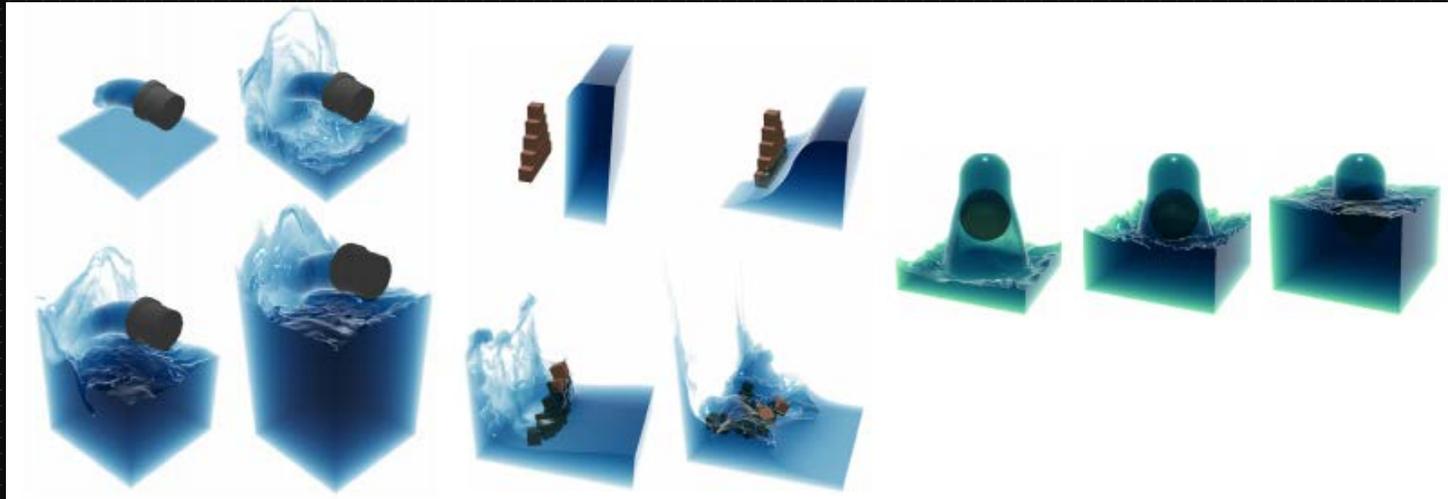
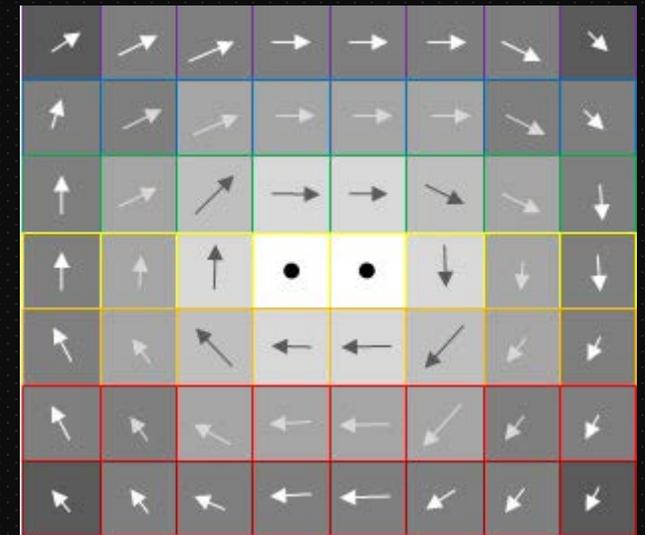
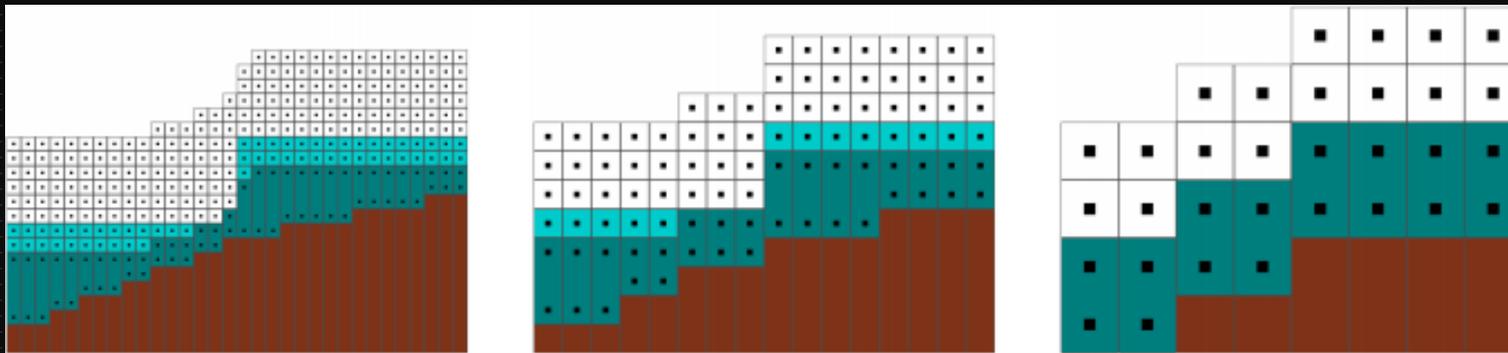


Image courtesy of: Chentanez, Muller, 2016.

Fluid Physics

- Field Based System:
 - Treats the fluid as a whole as a field
 - Each point in the field is assigned a set of properties
 - The position of the field points never move.
 - Real time simulations use 2 and a half D height field representation



Fluid Physics

- Particle Based System:
 - Treats the fluid as a whole as a body of particles
 - Each particle is assigned properties
 - The particles represent a certain portion of the fluid
 - Each particle is able to collide with every other particle and actor in the scene



Image courtesy of: Gourlay, 2016 and Green 2016.

Fluid Physics

- Combining the Two Systems:
 - Eulerian grid performs the physical simulation
 - Lagrangian method picks up the result of the simulation and particles move.

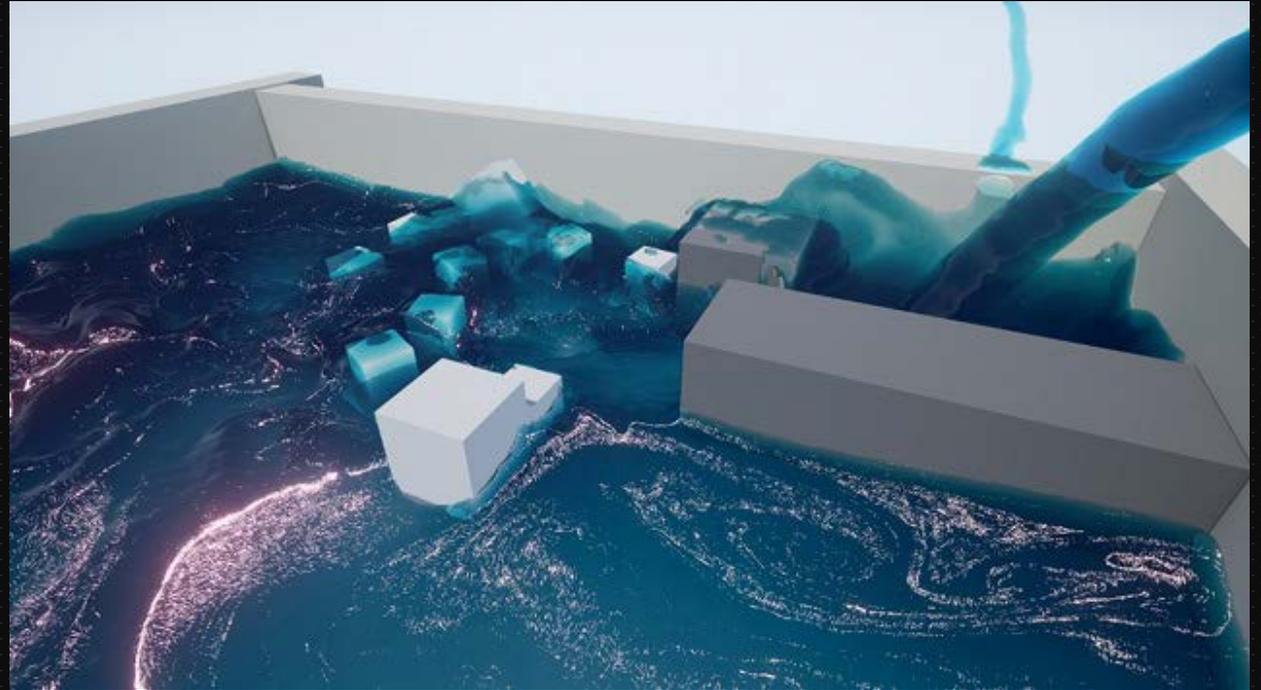


Image: Nvidia Cataclysm demo

Current Applications of Real Time Physics

- Particle Physics
 - Used in most modern games
 - Used for almost all effects
 - Accompany animation
- Collision Physics
 - Used for collision detection and response
 - Almost every modern game has some form of collision detection taking place



Image: *Battlefield 1*, DICE, Open Beta 2016

Current Applications of Real Time Physics

- Rigid Body Physics
 - Used for destruction of solid actors such as concrete or wood which shatter rather than bending.
 - Almost every 3D game has rigid body simulation of player interactivity.



Image: *The Witcher 3: Wild Hunt*, CDProjektRed, 2015

Current Applications of Real Time Physics

- Soft Body Physics
 - Generally only used in large studios
 - Used for hair, cloth and advanced destruction
 - Notable is BeamNG.drive featuring a real time soft body simulation for vehicles



Image: *BeamNG.drive*, BeamNG, 2016, Alpha

Current Applications of Real Time Physics

- Fluid Physics
 - True simulations haven't been used in modern games
 - Valve created fluid effects in Portal 2 using a solution called metaballs



Image: *Portal 2*, Valve Corporation, 2011



Application of Physics in The Barn

- Particle Physics are being used for ambience effects such as:
 - Fire
 - Smoke
 - Steam
 - Destruction decal
- Inexpensive and adds greater immersion
- Can be activated by collisions

Application of Physics in The Barn

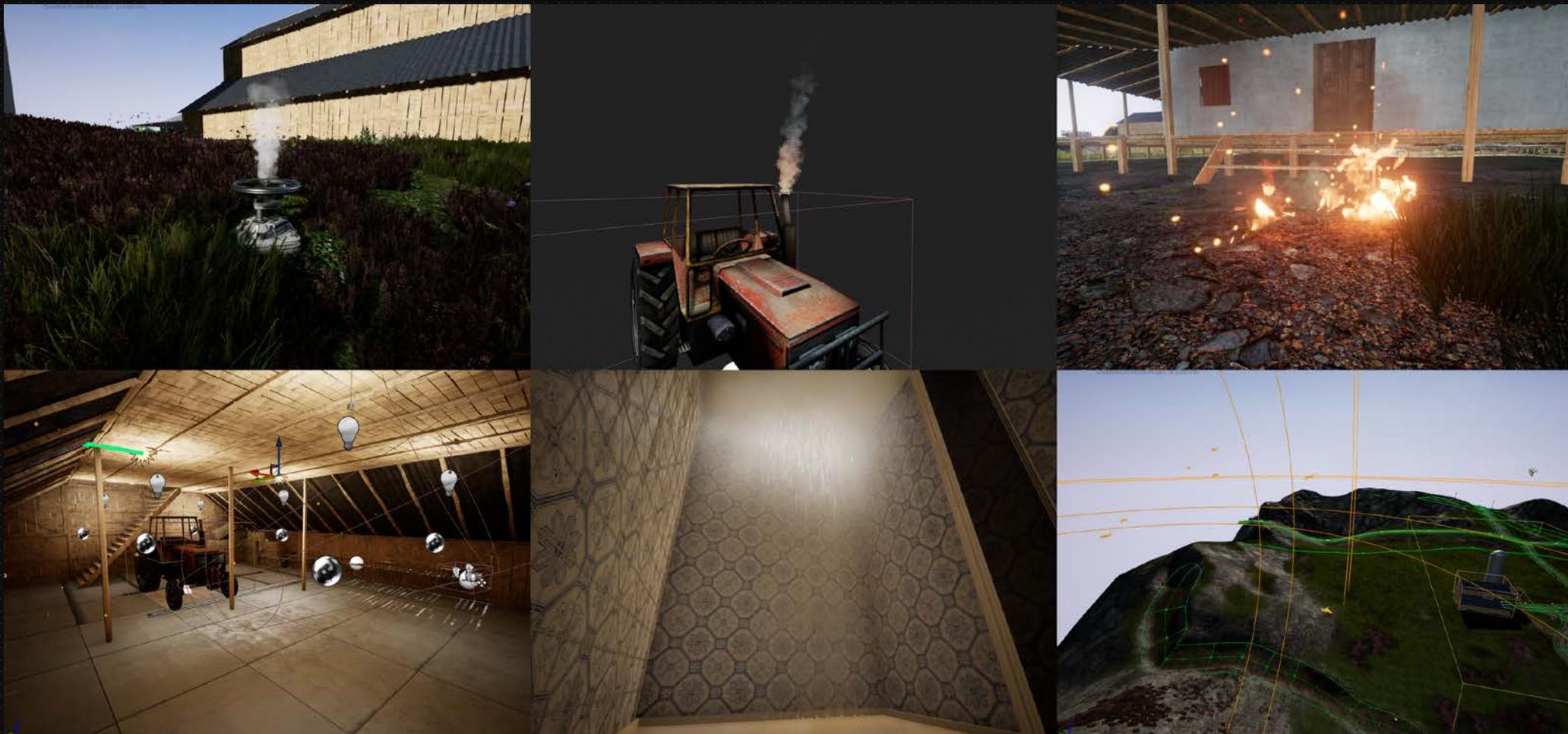


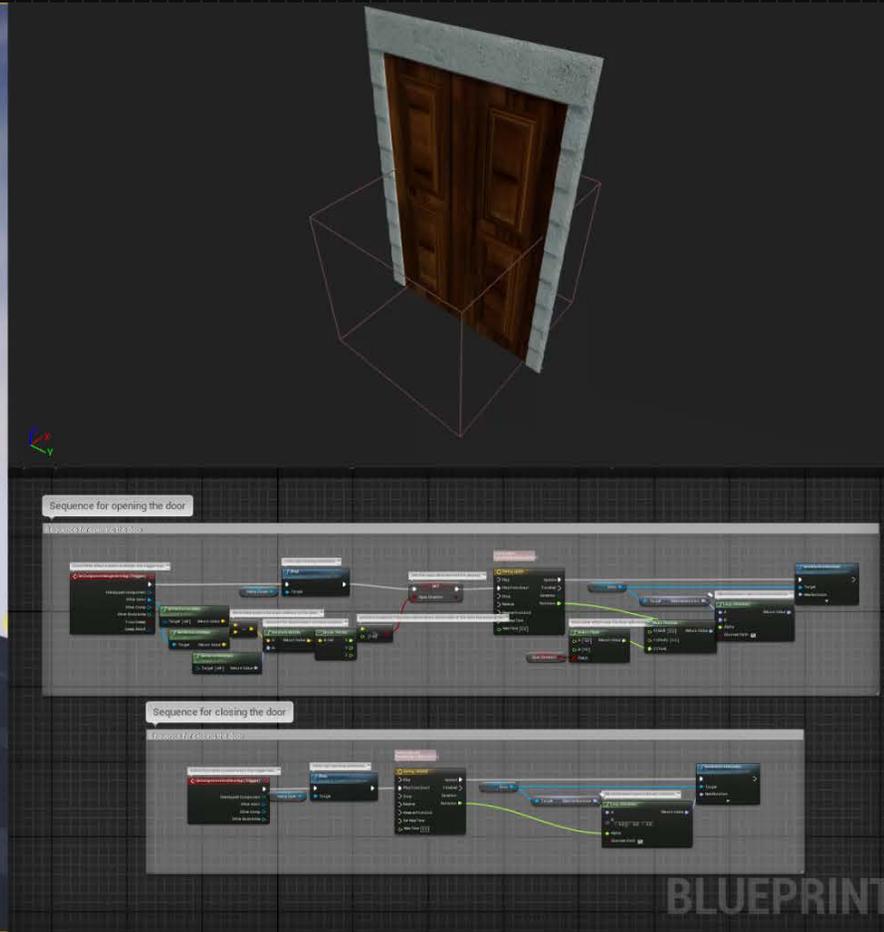
Image: Different particle effects used in The Barn



Application of Physics in The Barn

- Collision physics:
 - Collision response
 - Triggers
 - Door Opening
 - Enabling input
 - Block actor from passing through
 - Determine areas where player can walk
 - Change PhysX status i.e. set object awake or asleep
 - Collisions are used for almost everything

Application of Physics in The Barn



Video: Using collision responses to open and close a door



Application of Physics in The Barn

- Rigid Body physics:
 - Simulate gravity
 - Using collisions can simulate destruction of actors
- Generally used for basic simulation of gravity obeying objects

Application of Physics in The Barn



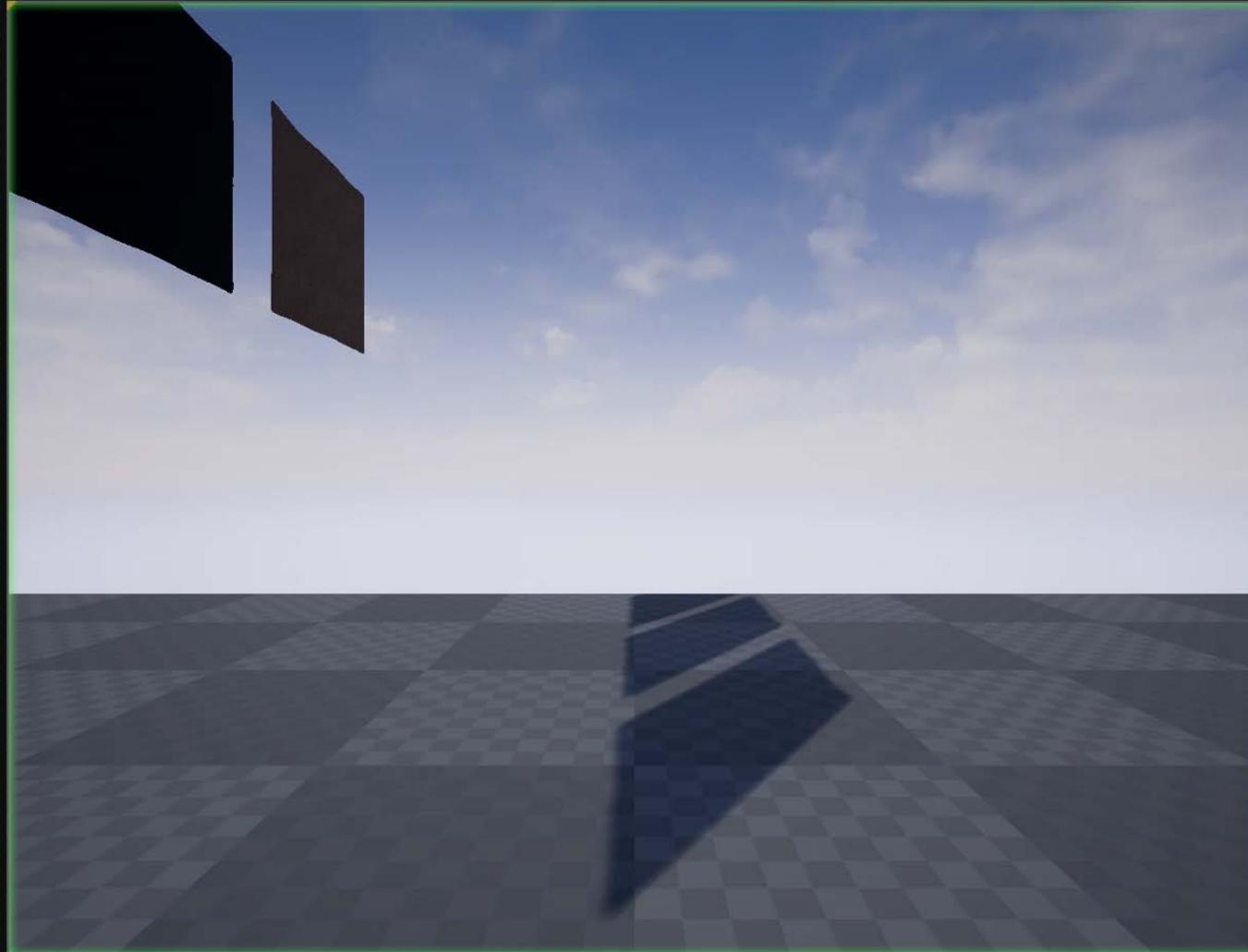
Video: Using rigid bodies to simulate destruction using collisions, player controlled impulse and non-destructible meshes



Application of Physics in The Barn

- Soft Body physics:
 - Used for deformable objects
 - Applying to hair, clothing and possibly for soft body destruction
- Will be limited in application due to performance and time.

Application of Physics in The Barn



Video: Test for simple cloth soft body physics and developing soft body simulation for hair using Apex

Future of Physics in Real Time

- The future looks promising for real time physics
- We will see more immersive gameplay, realistic physical results from collisions
- With advancements such as:
 - Nvidia's Cataclysm
 - AMD TressFX
 - Nvidia's APEX
- More cinematic real time environments



AMD TressFX Demo in *Tomb Raider* (2013)

Future of Physics in Real Time

- The application for real time physics is not limited to games
- Possibilities for medical applications
- Cinema and film applications
- Scientific real time imaging and visualisation
- Production visualisation and testing

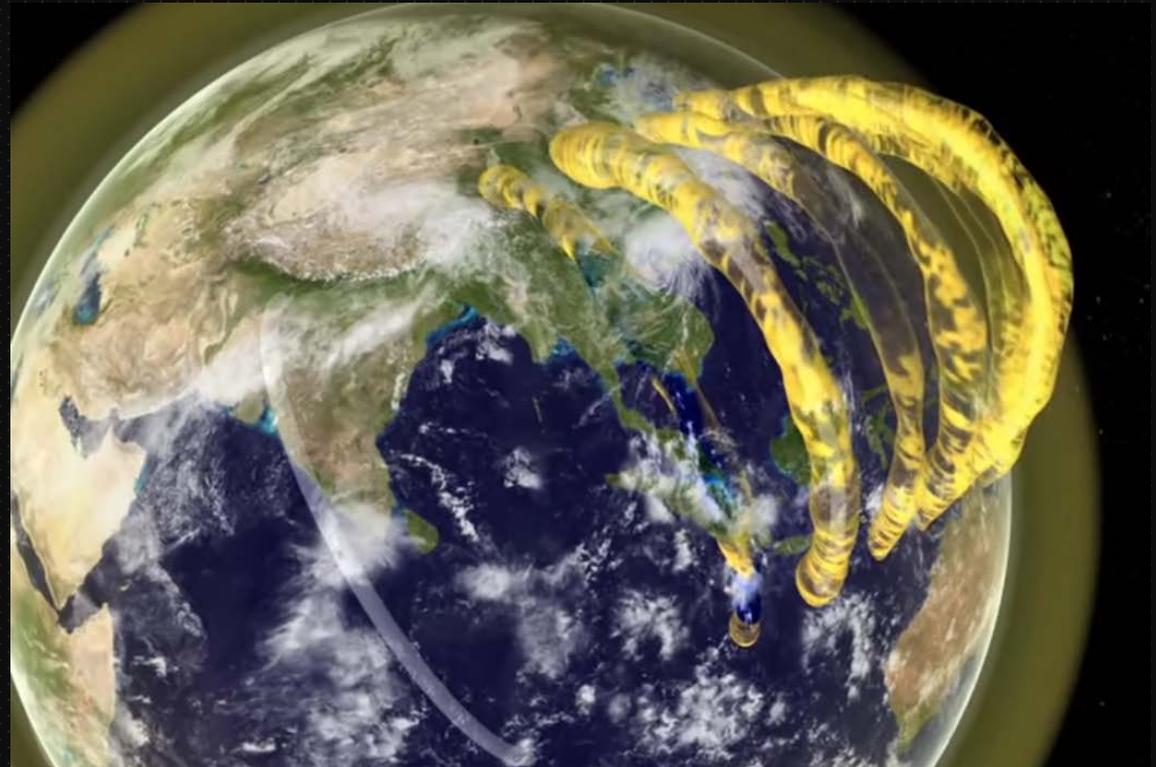


Image courtesy of: Loi, 2016.



Thankyou

To watch the progress of the Barn visit:

thebarnofficial.weebly.com