Advanced Character Physics

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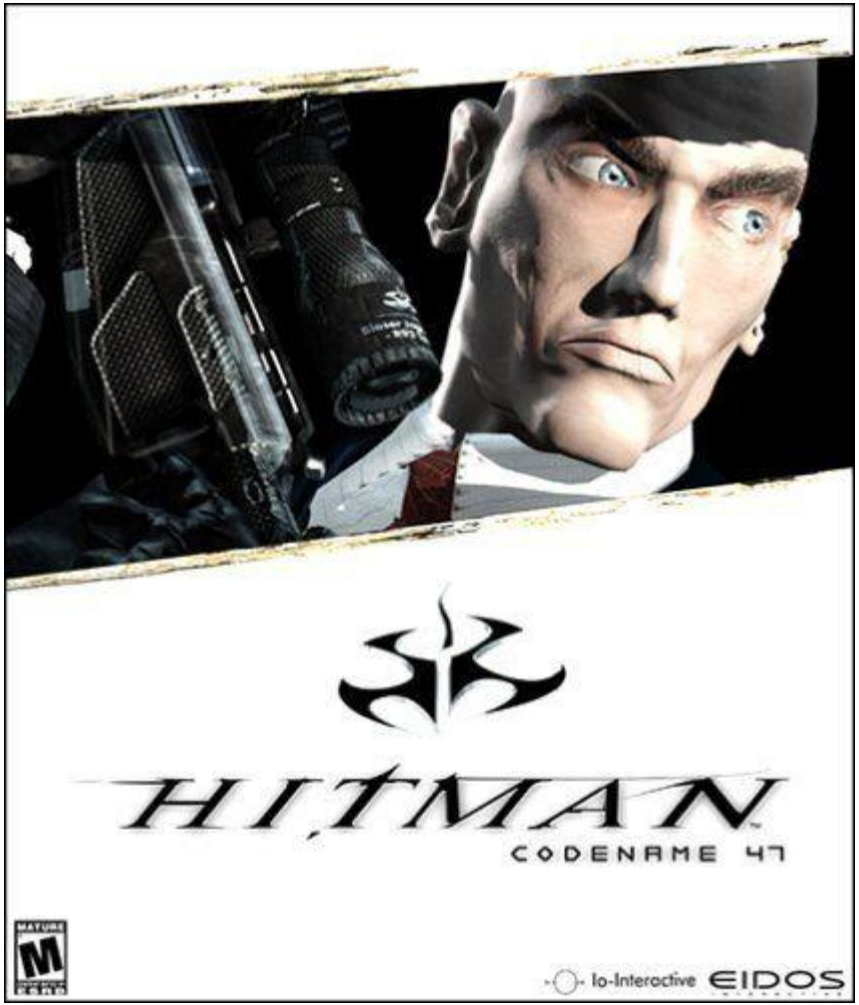
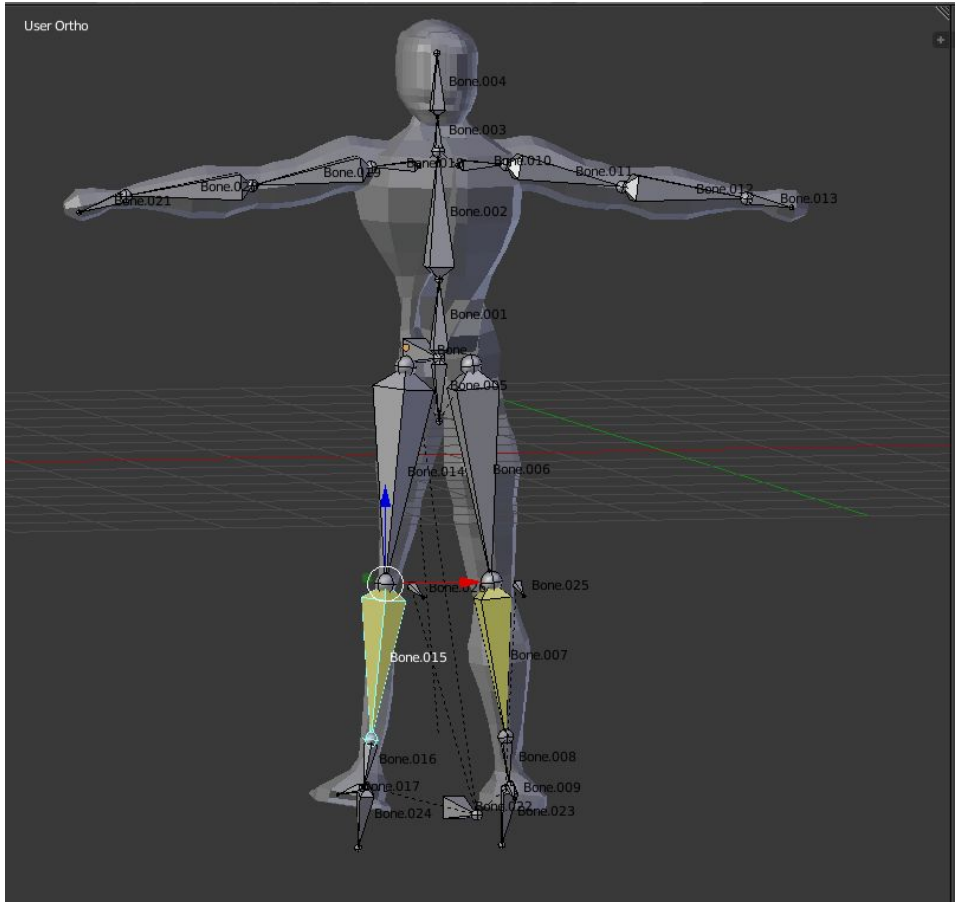
Abstract

The research paper was developed by IO Interactive for their Nov, 2000 game Hitman: Codename 47. Written by **Thomas Jakobsen**, the paper breaks down methods of simulating physics in a real-time environment. The major goal was to bring “life-like death animations” by applying physics forces to animated characters. This is done by creating constraints in between vertices which maintain the edge length under physics forces. These stick constraints enable both cloth simulation and ragdoll physics on virtual characters.



Overview

1. Verlet Integration
2. Constraint Solvers using relaxation
3. Rigid Bodies
4. Collision detection
5. Applications - Ragdoll physics



Verlet Integration, what is it?

Euler Integration

$$\mathbf{x}' = \mathbf{x} + \mathbf{v} \cdot \Delta t$$

$$\mathbf{v}' = \mathbf{v} + \mathbf{a} \cdot \Delta t,$$

Verlet Integration

$$\mathbf{x}' = 2\mathbf{x} - \mathbf{x}^* + \mathbf{a} \cdot \Delta t^2$$

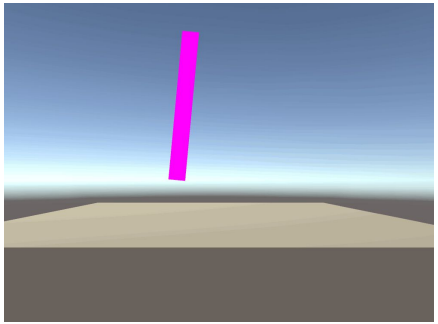
$$\mathbf{x}^* = \mathbf{x}.$$

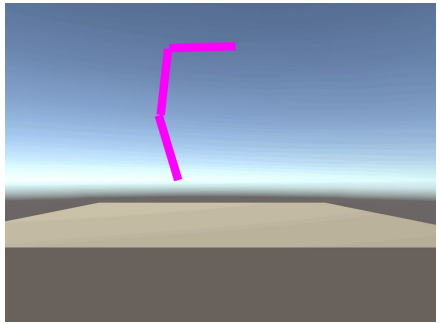
An alternative to the classic Euler integration method in that it allows skipping explicit velocity calculation.

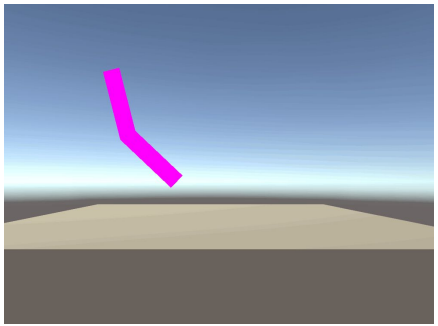
Very **fast and stable**, although not always accurate - perfect for real time physics.

Uses the **current position (x)** and the **previous position (x*)** to calculate the next position.

Constraints

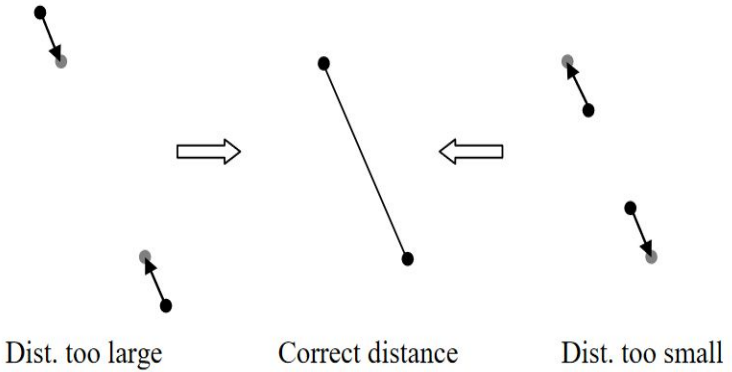






What is a constraint?

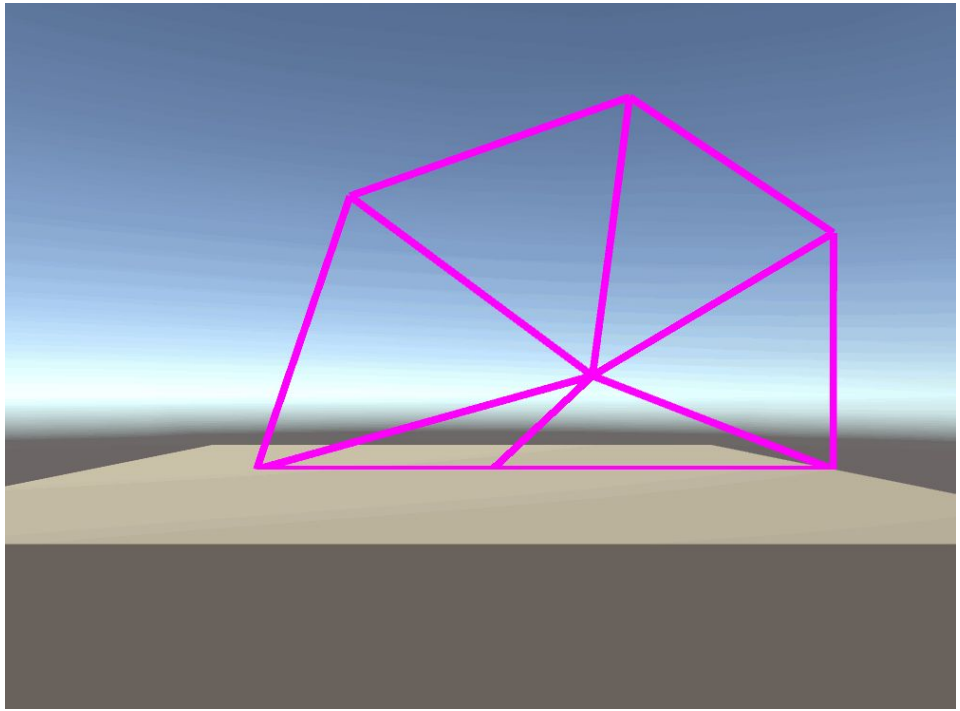
A line created between two particles, which keeps their size constant by pulling back and pushing together to its rest length.



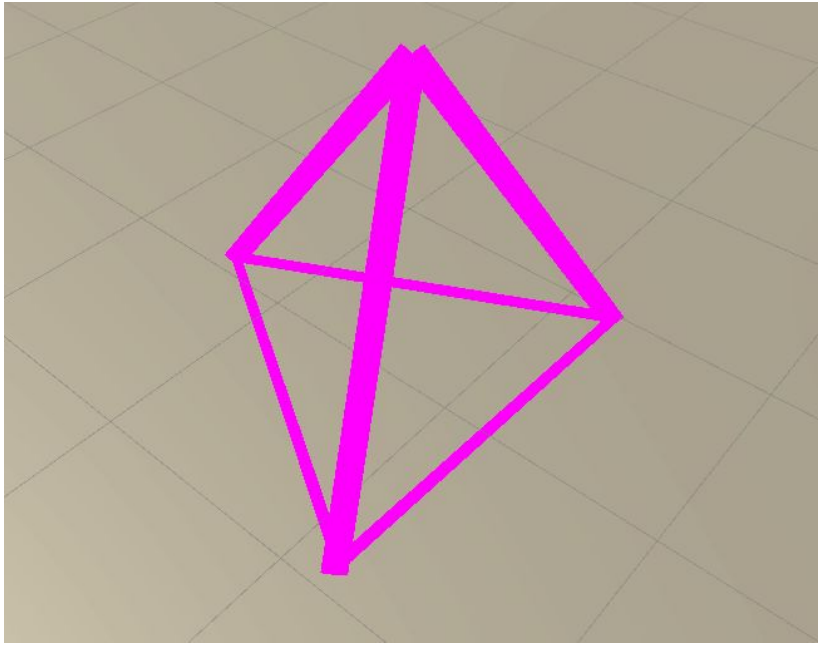
Cloth simulation

Combine multiple constraints together to create a mesh.

7 particles are stuck together with 12 constraints.



Rigid body



A **rigid body** is an object where the distance between two given points remains constant.

A tetrahedron is created using 4 particles and 6 constraints enabling movement in 3D space.

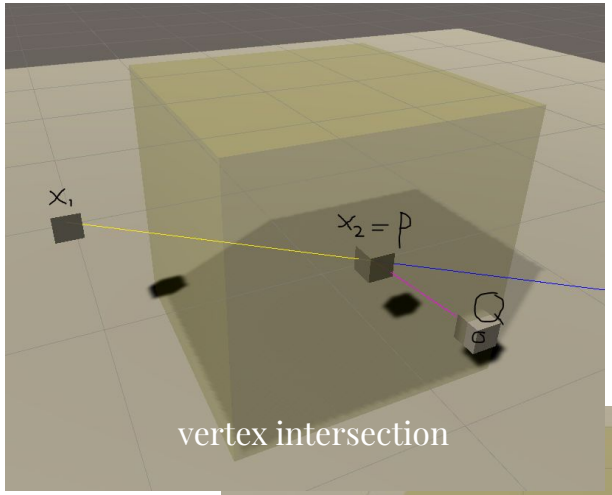
Collision Detection

Collision occurs when two objects intersect each other. The goal is to find point **Q** which will lead point **P** out of the intersection as quickly as possible.

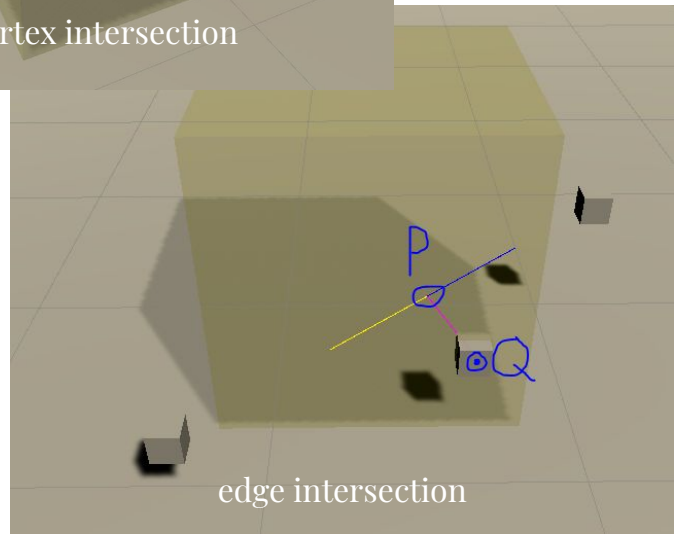
P is the center point of the constraint intersecting with the object.

Q is the closest point on the object's surface to **P**.

With this information we find a vector which moves P to Q, therefore exiting the object.



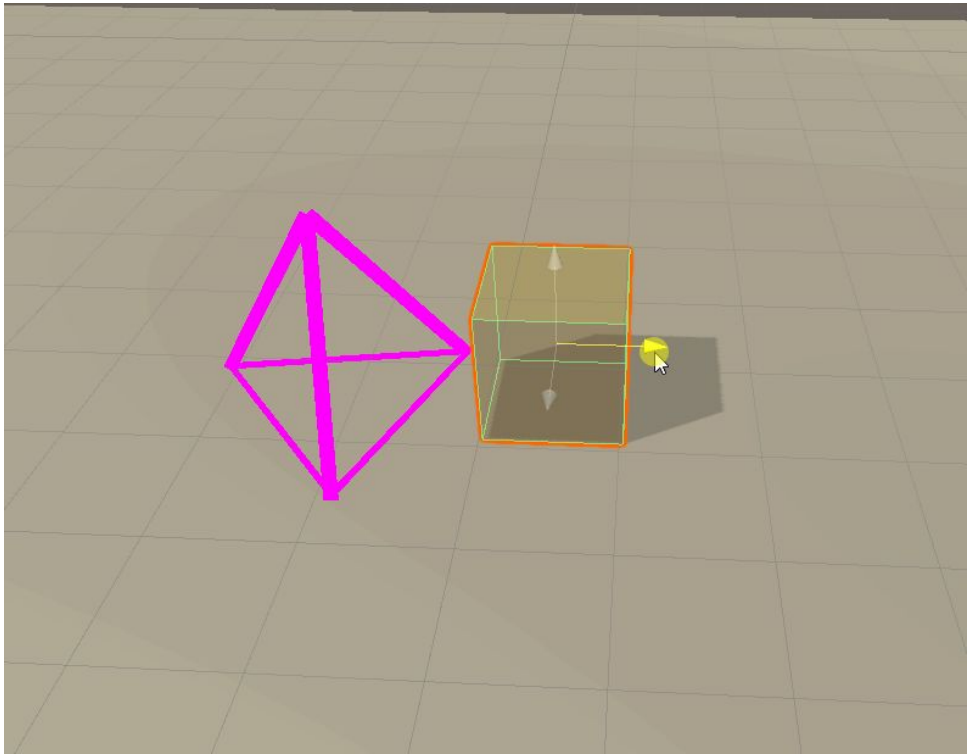
vertex intersection



edge intersection

Collision Applied

The impulse force is calculated at the constraints particle then applied to eject the object from the cube.



Results: Ragdoll Physics

Particle and constraint pairs can be combined to create more complex objects such as representing a human being.

These constraints will be applied on the character's bones rather than the mesh itself.