Advanced Cloth Simulation Using C++ and OpenGL

Amr Morsy - Zisen Ling - Christian Tesa

Demo

Overview

- The project implementation can be explained in 2 steps:

    1. Simulating Cloth

    2. Rendering Scene

Simulating Cloth

- Mass-spring systems provide a simple yet practical method for simulating cloths
- However, obtaining realistic material behaviors typically requires constitutive parameters that result in numerically stiff systems.
- Explicit time integration methods are fast but when applied to these stiff systems they have stability problems and are prone to failure

Simulating Cloth

- Traditional methods for implicit integration remain stable but require solving large systems of equations.

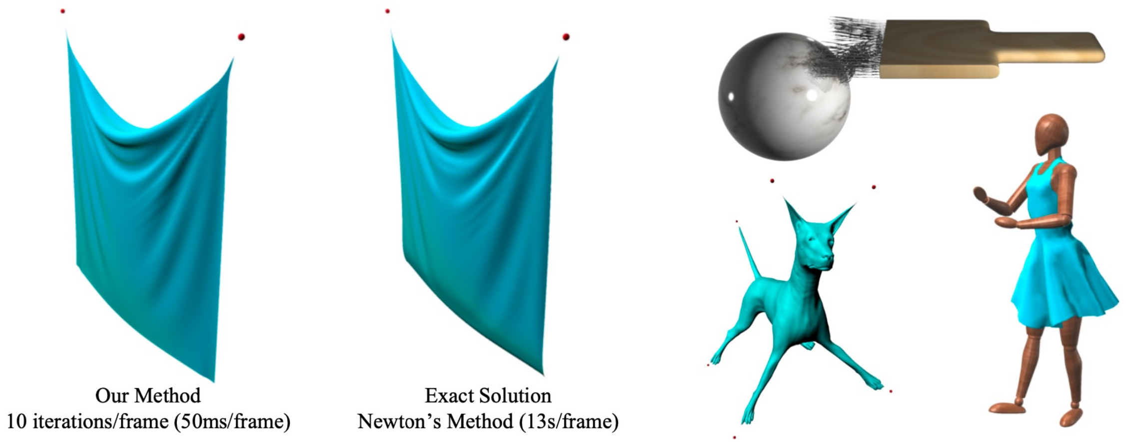
- The high cost of solving these systems of equations limits their utility for real-time applications.

Simulating Cloth

- However, the following research paper proposes a fast implicit solver for standard mass- spring systems with spring forces governed by Hooke's law

Fast Simulation of Mass-Spring Systems

Tiantian Liu, University of Pennsylvania
Adam W. Bargteil, University of Utah
James F. O'Brien, University of California, Berkeley
Ladislav Kavan*, University of Pennsylvania



http://graphics.berkeley.edu/papers/Liu-FSM-2013-11/Liu-FSM-2013-11.pdf

Simulating Cloth

- **Main idea:** The implicit Euler method can be expressed as an energy minimization problem. This minimization problem, then, can be solved using block coordinate descent method

Simulating Cloth

- The equation (a discretized version of Newton's second law F = Ma)

$$\mathbf{q}_{n+1} - 2\mathbf{q}_n + \mathbf{q}_{n-1} = h^2\mathbf{M}^{-1}\mathbf{f}(\mathbf{q}_{n+1})$$

$\mathbf{q}_{n-1}$: Vertices in the previous time step
$\mathbf{q}_{n}$: Vertices in the current time step
$\mathbf{q}_{n+1}$: Vertices in the next time step
H: Time step
$\mathbf{f}(\mathbf{q}_{n+1})$: Forces acting on the vertices in the next time step
$\mathbf{M}^{-1}$: Inverse Mass Matrix

Simulating Cloth

Is turned into an optimization problem

$$\min_{\mathbf{x}\in \mathrm{R}^{3m},\ \mathbf{d}\in U} \quad \frac{1}{2}\mathbf{x}^{\mathsf{T}}(\mathbf{M}+h^2\mathbf{L})\mathbf{x} - h^2\mathbf{x}^{\mathsf{T}}\mathbf{J}\mathbf{d} + \mathbf{x}^{\mathsf{T}}\mathbf{b}$$

The value of x that will minimize the above equation is the vertices in the next time step

Simulating Cloth

- Differentiating the equation and equating it to zero results in the final equation to be implemented:

$$\left(M+h^2L\right)\cdot x = h^2\cdot Jd - b$$

This linear equation will be solved using the technique Block Coordinate Descent (explained in the paper)

Rendering Scene

- The project features:
  - Physically-Based Rendering (PBR):
    - PBR simulates the way light interacts with surfaces, providing a more realistic and dynamic range of visual effects.
    - Used for rendering direct lighting and radiance, PBR enhances the realism of the cloth texture and its interaction with light.

Rendering Scene

- <u>Image-Based Lighting (IBL):</u>
  - IBL is a technique that uses images to create realistic lighting effects, particularly for indirect light sources
  - Implements indirect lighting and irradiance, adding depth and richness to the scene, especially in shadows and reflections

Rendering Scene

- HDR Skybox:

  - An HDR (High Dynamic Range) Skybox creates a more lifelike and vibrant background, offering a broader range of light and color intensities.

  - The HDR Skybox contributes to the overall lighting and ambiance of the scene, affecting how the cloth appears in different environmental settings.

Rendering Scene

- Fog Rendering:
  - Utilizes a simple exponential function to simulate fog, adding a layer of atmospheric depth to the scene
  - Fog rendering enhances the sense of realism and scale, particularly in large or outdoor scenes

Resources

- **Fast Simulation of Mass-Spring Systems:** http://graphics.berkeley.edu/papers/Liu-FSM-2013-11/Liu-FSM-2013-11.pdf
- **3D Models:** https://www.cgtrader.com
- **PBR Materials:** https://freepbr.com/c/base-metals/
- **HDR Skybox:** https://polyhaven.com/hdris/skies

Questions ?

Thank You