CAMA: Contact-Aware Matrix Assembly with Unified Collision Handling for GPU-based Cloth Simulation

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http://gamma.cs.unc.edu/CAMA/

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Abstract

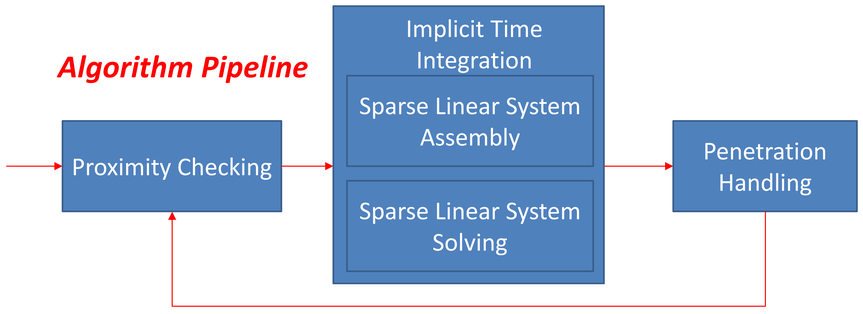
We present a novel GPU-based approach to robustly and efficiently simulate high-resolution and complexly layered cloth. The key component of our formulation is a parallelized matrix assembly algorithm that can quickly build a large and sparse matrix in a compressed format and accurately solve linear systems on GPUs. We also present a fast and integrated solution for parallel collision handling, including collision detection and response computations, which utilizes spatio-temporal coherence. We combine these algorithms as part of a new cloth simulation pipeline that incorporates contact forces into implicit time integration for collision avoidance. The entire pipeline is implemented on GPUs, and we evaluate its performance on complex benchmarks consisting of 100-300K triangles. In practice, our system takes a few seconds to simulate one frame of a complex cloth scene, which represents significant speedups over prior CPU and GPU-based cloth simulation systems.

Motivation

To design a highly parallel and robust GPU-based cloth simulation algorithm. Challenges:

- Flexibility in terms of mesh representations, time integration, and collision response
- Fast and robust collision handling
- Dynamic matrix assembly for implicit integration on GPUs

Algorithm Pipeline



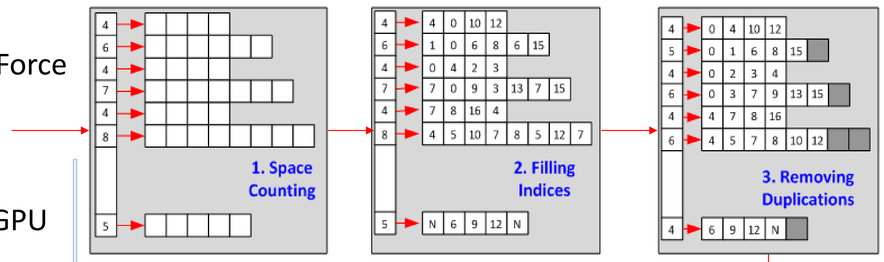
Main Results

A novel cloth simulation algorithm on GPUs

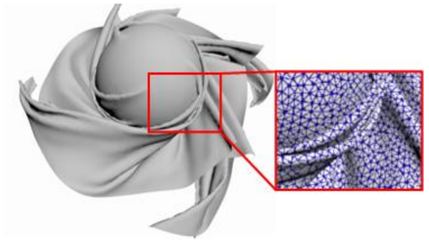
- Unified streaming pipeline for time integration and collision handling
- Parallel sparse matrix assembly algorithm supports :
  - Implicit time integration
  - Cloth models with arbitrary topology
- Integrated collision detection & response
- Parallel collision response algorithm based on inelastic impact zones
- Faster collision detection based on localized propagation
- 30X speedup over CPU-based algorithms/ implementations

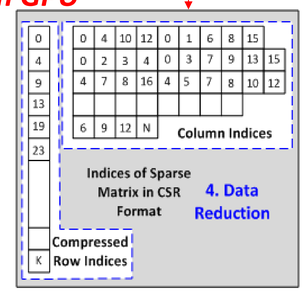
Performance

- Implemented on different NVIDIA GPUs (GeForce GTX 780, Tesla K20c, and Tesla K40c)
- Complex benchmarks: 100K-300K triangles
- Average frame time: a few seconds
- Considerable speedups over prior CPU and GPU algorithms



Parallel Sparse Matrix Assembly on GPU





Publication

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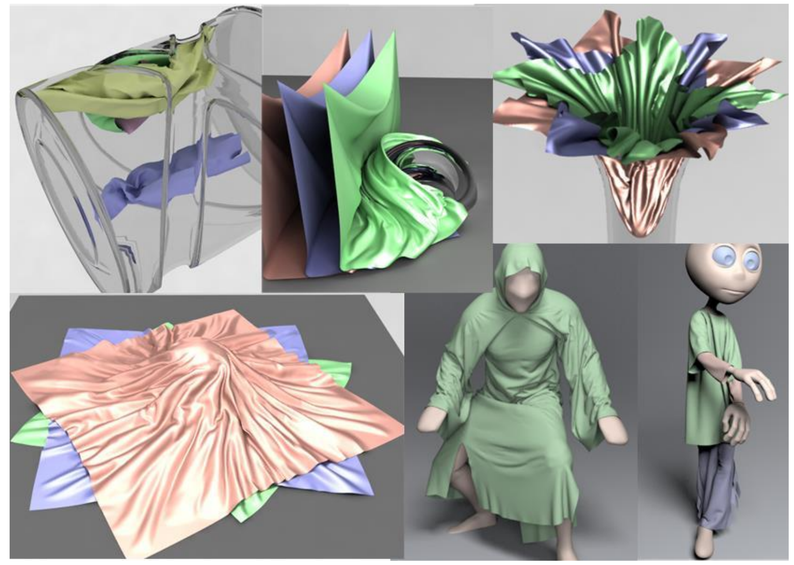

Benchmarks