CATEGORY: **COMBINED SIMULATION AND REAL-TIME VISUALIZATION**

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GPU TECHNOLOGY CONFERENCE

Exact Soft-Body Collision Detection on the GPU

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Overview

Soft-body collision detection is an open problem in physical simulations of deformable objects such as cloth and hair. Current methods are either too computationally expensive, or rely on gross approximations that yield significant errors.

We present a new method that accurately detects soft-body collisions, specifically the edge-edge collisions that most other methods would miss, interactively on modern GPUs. Our method guarantees that no pass-through will occur between objects by using interpolation equations to represent motion between time steps, yielding nearly exact collision times and responses. GPU acceleration via CUDA allows this method to operate at interactive rates.

Methodology

Both types of collisions are solved discretely using interpolation equations, allowing increased accuracy by providing an exact time and location for each collision as it occurs. For Vertex-Face collisions, we compute the interpolation value along the path of particle p between time steps.

To interpolate between time steps for Edge-Edge collisions, we first require an equation to define every point along the two dimensional strip swept out by an edge between time steps. This equation defines both the spatial translation and rotation of the Edge N in three dimensions.

Collisions are then determined by setting the equations for Edge N and Edge M equal and solving the resulting system for the interpolation variable t, giving an exact solution for Edge-Edge collisions.
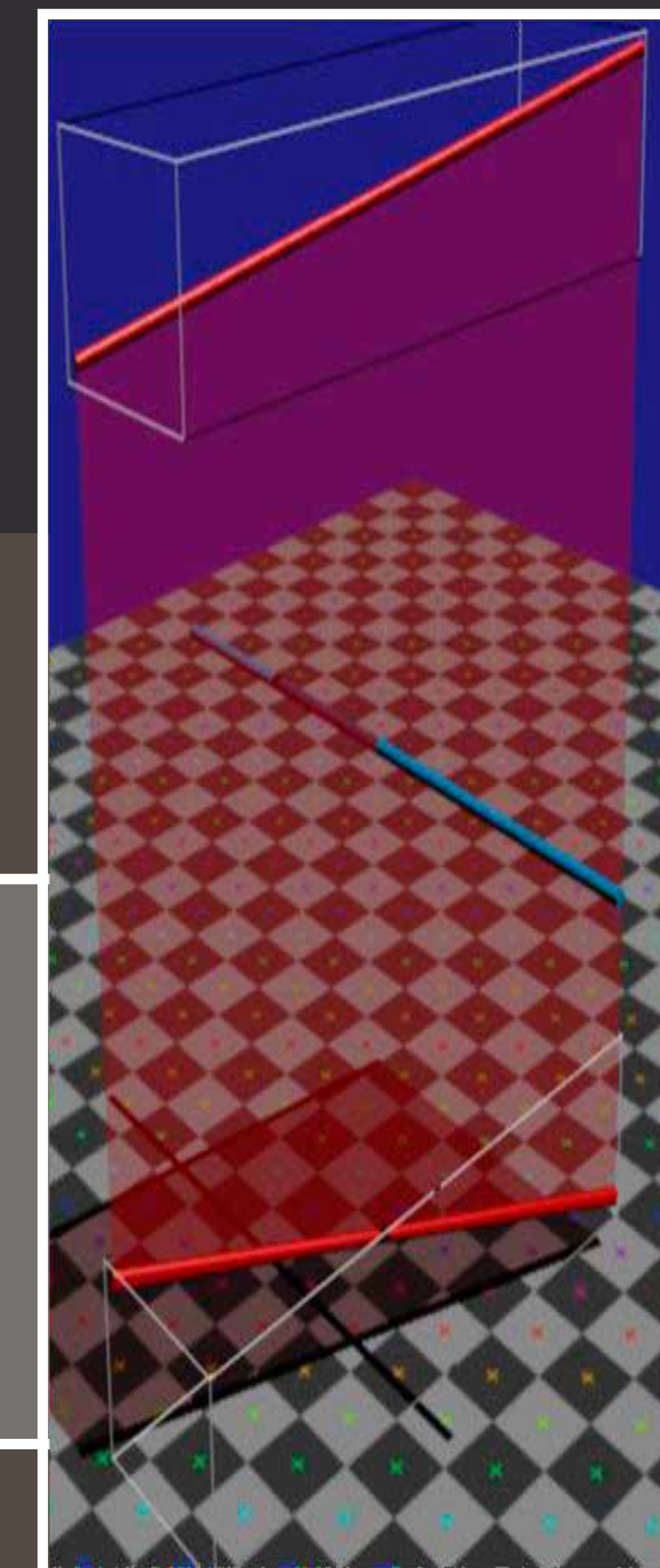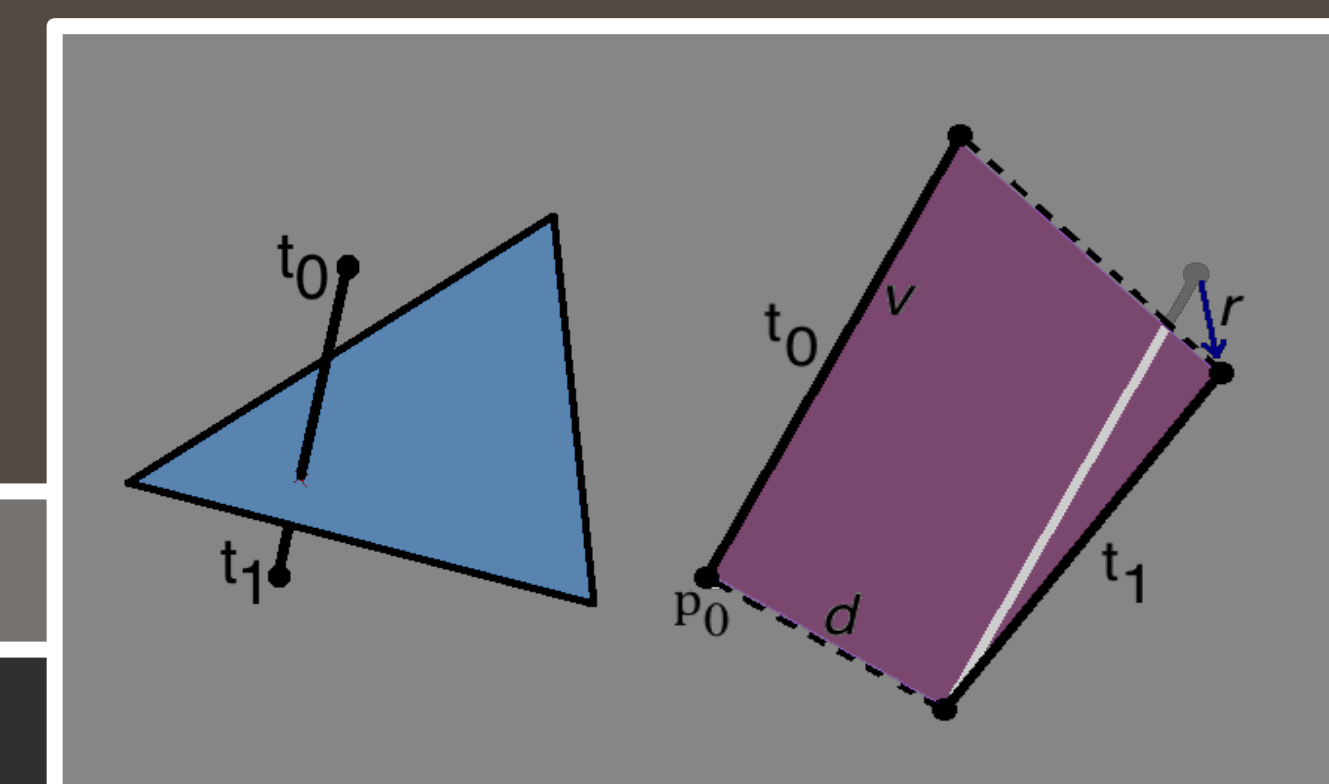
$$l_n \begin{bmatrix} v_{xn} + t \cdot r_{xn} \\ v_{yn} + t \cdot r_{yn} \\ v_{zn} + t \cdot r_{zn} \end{bmatrix} + \begin{bmatrix} x_{0n} + t \cdot dx_n \\ y_{0n} + t \cdot dy_n \\ z_{0n} + t \cdot dz_n \end{bmatrix}$$
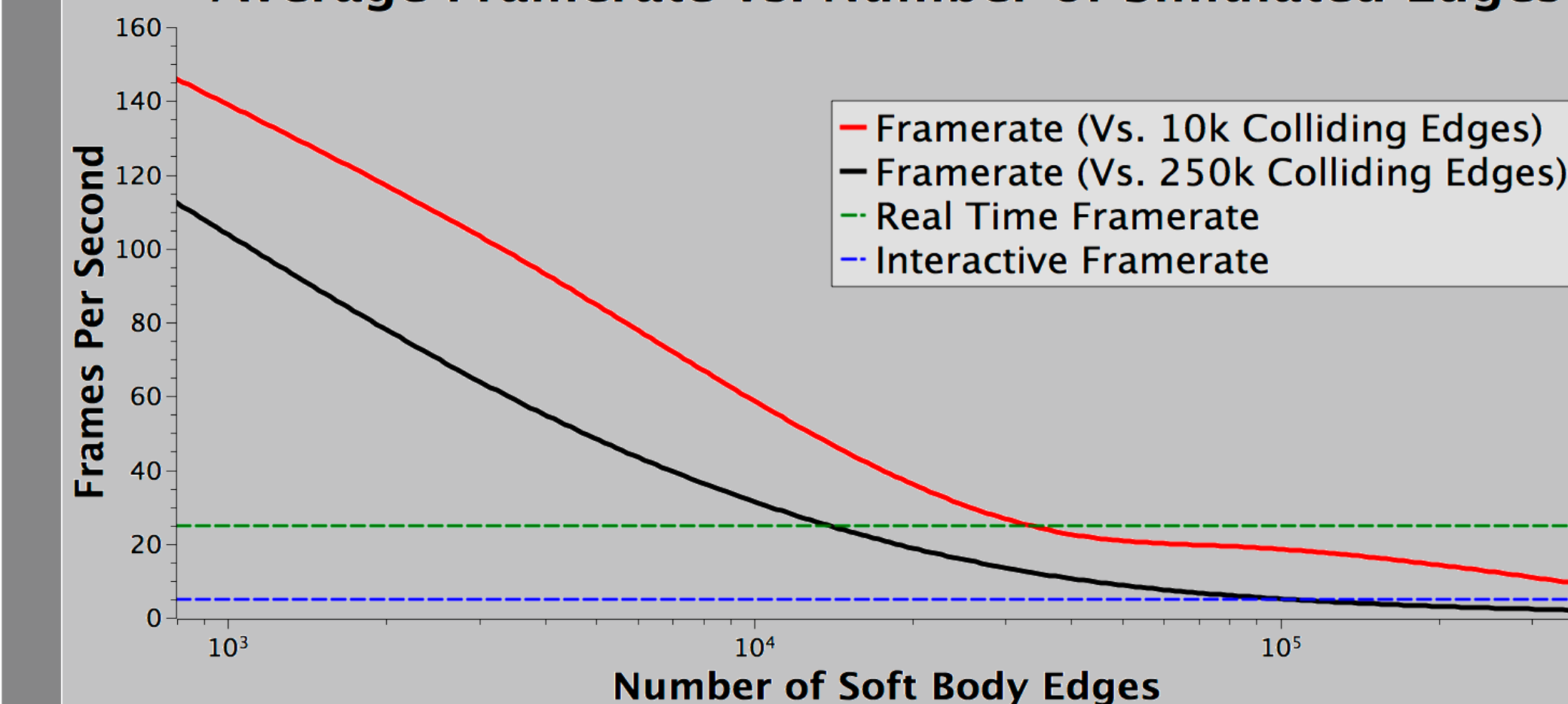
Collisions

We identify two types of collisions that may occur between two dynamic objects:

- Vertex-Face collisions, in which a point mass passes through the face of a colliding polygon. These collisions simplify to Ray-Triangle intersections.

- Edge-Edge collisions, which occur when the line segment formed between two point masses crosses the edge of a colliding polygon. These collisions are generally not handled by common collision detection methods, resulting in object pass-through.

Results

Tests were conducted using a GeForce GTX 680 on a range of 1-500 simulated cloth strands. Data shows that, for even large collision models, interactive simulation speeds can be obtained with hundreds of thousands of simulated point masses and edges.

Conclusions

Our methods detect all collisions (Vertex-Face and Edge-Edge) between soft-body objects and static rigid models, both quickly and accurately.

We have also solved these equations for two dynamic edges, such as self-collisions and collisions with moving objects. Future work will include incorporation of the dynamic Edge-Edge collision equations into our engine.

Average Framerate vs. Number of Simulated Edges