Recent Advances in Real-Time Collision and Proximity Computations for Games and Simulations

Organizer:

- Sung-eui Yoon

Lecturers (alphabetic order):

- Stephen Frye, Takahiro Harada, Young J. Kim, and Sung-eui Yoon

Half day tutorial:

- This tutorial targets for beginner-level and intermediate-level students/researchers. As a result, this tutorial assumes only a basic background on computer graphics; undergraduate level understanding on computer graphics should be okay.

Keywords:

- Collision detection, distance computation, proximity queries, bounding volume hierarchies, parallel computation

Abstract:

This course is intended for instructing students and practitioners on recent developments related to collision and proximity computations for interactive games and simulations.

There have been significant advances in various physics-based simulation techniques for movies, interactive games, and virtual environments. Most recent work has been on achieving realistic simulations of rigid, articulated, deforming, and fracturing models. However, many complex and challenging simulations (e.g., fracturing simulation) are not widely used in interactive games because of their computational requirements, although the hardware capability of current CPUs and GPUs has considerably improving. It is well known that one of the main performance bottlenecks in most simulations lies in proximity queries including collision detection, minimum separation distance, and penetration depth computations.

As a result, there has been significant recent research on developing real-time proximity computation algorithms for interactive games and high-quality simulations. Some of recent advanced techniques are able to achieve interactive performance even for most challenging simulations such as fracturing or large-scale cloth simulations. However, these techniques are quite complicated. Moreover, they require in-depth geometric background and sophisticated optimizations on multi-core architectures. These techniques, therefore, have not been easily accessible to students and practitioners who work on real-time simulation methods.

Our objective is to introduce and teach students and practitioners about efficient proximity computation methods and their practical implementations. By doing so, we can expose the attendees to the latest developments, to bridge the gap between the two different fields: proximity computation and simulation. At a broad level, this course will cover the following topics:

- Basic algorithms for various proximity queries including collision detection, minimum separation distances, penetration depth, etc.
- Discrete and continuous algorithms for rigid, articulated, deforming, and fracturing models.
- Parallel algorithms that utilize many cores of CPUs, GPUs, or CPUs/GPUs.
- Applications of various proximity queries in Havoc, a widely used Physics simulation package
- Optimized proximity data structures for many-core architectures including GPU
- Integrating proximity computation algorithms into physically-based simulation systems.

We have four instructors from academia and industry, each of who has significant experiences in designing and implementing different aspects of the aforementioned teaching materials. Since each instructor is a world-class expert in his field, students will receive the best instruction. Moreover, students and practitioners can learn how the industry-leading physics systems benefits from efficient proximity queries.

Prior courses:
To the best of our knowledge, there have been no courses on topics similar to ours, at least within the last three years at Eurographics. However, we have offered a similar course at SIGGRAPH and SIGGRAPH Asia at 2010. There were about 100 audiences in each of these tutorials. We would like to offer a similar course at Eurographics conference, mainly for European audience who did not attend these conf. Also we will cover recent techniques that have been developed in academy and industry for last 2 or 3 years. We have one more researcher from European country to cover recent developments made by European community. In this regard, Stephen Frye at EA-UK (physics team leader at EA) joined our tutorial team and will give a talk on what he is working on collision/simulation related topics.

Proposed Schedule: (2 * 90 minutes)

(Monday, May 14th, 13:20-16:40 (Half Day) in Room C)

1:20pm: Introduction (Yoon)
1:40pm: Real-time continuous collision detection and penetration depth computation for rigid and articulated characters (Kim)
2:20pm: Collision detection for deformable and fracturing models (Yoon)

3:00pm: 20 min. break

3:20pm: Recent parallel techniques for collision detection and its application to physics simulation on the GPU (Harada)
4:00pm: Playing with Collisions (Frye)

4:40pm: Close

Talk Syllabus:

1. Introduction (Yoon)

Summary: We explain a basic collision detection method based on a bounding volume hierarchy. We explain how to perform inter- and intra-collision detection methods in an efficient manner, followed by discussing the difference between discrete and continuous collision detection. We also introduce other related proximity queries (e.g., minimum separation distance).

Syllabus:

- Basic collision detection methods
- Bounding volume hierarchies and their operations
- Self- and inter-collision detection methods.
- Discrete and continuous detection methods.

Sung-eui Yoon:

- KAIST
- IWON Associate Professor at KAIST
- http://sglab.kaist.ac.kr/~sungeui, sungeui@gmail.com
- He received the B.S. and M.S. degrees in computer science from Seoul National University in 1999 and 2001 respectively. He received his Ph.D. degree in computer science from the University of North Carolina at Chapel Hill in 2005. He was a postdoctoral scholar at Lawrence Livermore National Laboratory. His research interests include scalable proximity computations and interactive ray tracing for massive models. He has published more than 30 technical papers in top journals and conference related to visualization and graphics. He serves on various program committees. One of his work received a distinguished paper award at Pacific Graphics at 2009.

2. Real-time Continuous Collision Detection and Penetration Depth Computation for Rigid and Articulated Characters (Kim)

Summary: Maintaining the non-penetration constraint is a crucial problem for realistic simulations of rigid and articulated bodies. Recent researches show that the two seemingly conflicting approaches based on penetration avoidance and recovery turn out to be complementary to each other and are both useful for imposing the non-penetration constraint. In this talk, we present a penetration avoidance technique based on continuous collision detection (CCD) by taking into account of the underlying character motion. We also explain a penetration recovery technique based on penetration depth (PD) computation. Finally, we describe a practical method to implement these collision and penetration queries in a relatively simple manner, which can guarantee interactive performance at run-time, and also demonstrate how these queries can be integrated into real-time physics simulation.

Syllabus:

- Continuous collision detection algorithms for rigid models
- Continuous collision detection algorithms for articulated models
- Penetration depth computation for rigid models
- Application of continuous collision detection and penetration depth to real-time physics simulation

Young J. Kim:

- Associate Professor at EWHA womens university
- http://graphics.ewha.ac.kr, degreeskimy@ewha.ac.kr
- He received his BS and MS degrees in Computer Science and Statistics in 1993 and 1996, respectively, from Seoul National University, and received his PhD in computer Science in August 2000 from Purdue University. Before joining Ewha, he has been a Postdoctoral Research Fellow in the Department of Computer Science at the University of North Carolina (UNC) at Chapel Hill. His research interests include interactive computer graphics, computer games, robotics, haptics and geometric modeling. He has published more than 50 papers in leading conferences and journals in these fields. He also received the best paper awards at the ACM Solid Modeling Conference in 2003 and International CAD Conference in 2008, and the best poster award at the Geometric Modeling and Processing conference in 2006. He is a recipient of the Young Investigator Award from Korean Ministry of Science and Technology (MOST) in 2004 and best research faculty at Ewha Womans University in 2008 and outstanding research cases award from the Korean research foundation in 2008.

3. Collision Detection for Large-Scale Deforming and Fracturing Models (Yoon)

Summary: Many physically-based simulations used in games and movies are heavily using different types of deforming models. Unlike handling rigid models, deforming models can have self-collisions. Therefore, the performance of collision detection for deforming models has been known to be significantly slower than that for rigid bodies. In this talk, we describe various optimization methods that have been designed recently to improve the performance of discrete and continuous collision detection for deforming models. We also cover most recent techniques designed for fracturing simulations, which are one of the most challenging simulations in terms of collision detection.

Syllabus:

- BVH update and reconstruction methods for deforming and fracturing models
- Efficient self-collision detection method
- Various culling techniques for intra- and self-collisions
- Hybrid parallel algorithms

4. GPU-based collision detection and proximity computations (Harada)

Summary: The trend of processor technology is to increase the number of cores on a processor. On these processors, technologies developed for a single core processor cannot be used to achieve high performance. Thus, developing technologies for these parallel processors are getting more and more important. This session starts with an introduction of parallel computation on the GPU. Later, it presents recent techniques for collision detection and its application to physics simulation on the GPU.

Syllabus:

- GPU-friendly rigid and paticle-based simulations
- GPU-friendly collision detection methods
- Techniques using multiple GPUs
- Parallel contact handling

Takahiro Harada:

- Member of Technical Staff at Advanced Micro Devices, Inc.
- http://www.iii.u-tokyo.ac.jp/~takahiroharada/, Takahiro.Harada@amd.com>
- Takahiro Harada is a member of technical staff in AMD's GPU CTO team where he is focusing on physics simulation. Before joining AMD, he did R&D on physics simulation at Havok. Before leaving his country, he was an assistant professor at the University of Tokyo. He earned his Ph.D. in engineering from the University of Tokyo as well.

5. Playing with Collisions (Frye)

Syllabus:

- General talk about collision pipelines in games (broad-phase, mid-phase, narrow phase, contact manifolds)
- Some discussion about the pipeline in FIFA
- Some discussion about the pipeline in SSX (including talking about meshes)

Stephen Frye:

- Physics team leader in EA-UK

Sample slides are given in below.