# CSCI 520 Computer Animation and Simulation
# Spring 2013


| Spring 2013, Monday and Wednesday, **2:00-3:20, MHP B7B** | |
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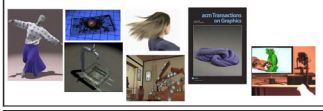
| Instructor: Jernej Barbic<br>Office: SAL 230<br>Office hours: Wednesday 3:30 - 5:00<br>Email: jnb@usc.edu | TA: Yili Zhao<br>Office: SAL 235<br>Office hours: Tuesday 1:00 - 3:00<br>Email: yilizhao@usc.edu |

**Introduction and Purposes**

This course introduces students to computer animation and related simulation techniques, as applicable to computer games, virtual reality systems, and film special effects. Efficient numerical methods for simulating a variety of visually interesting physical phenomena will be discussed in the context of both interactive and offline simulation. Topics include deformable objects (solids, cloth), fluids, character rigging, quaternions, inverse kinematics, motion capture, sound simulation, collision detection, haptics, rigid body dynamics, and GPU programming.

**Schedule** | **Prerequisites** | Readings | **Assignments** | **Grading** | **Class participation** | Academic Integrity

| Date | Topic | Reading, slides, and other material | Notes |
|---|---|---|---|
| Mon Jan 14 2013 | Overview of computer animation and simulation  | Course slides | |
| Wed Jan 16 | Overview of computer animation and simulation | | |
| Mon Jan 21 | No class (Martin Luther King Day) | | |
| Wed Jan 23 | Primer on numerical simulation and linear algebra for graphics | D. Baraff and A. Witkin: Physically Based Modeling, course notes, SIGGRAPH 2001 | **Assignment 1 out** |
| Mon Jan 28 | OpenGL | OpenGL Red Book, Chapters 1-3<br>CMU slides on OpenGL<br>OpenGL "Hello world" application (with GLUT) Makefile (Mac OS X) | |
| Wed Jan 30 | OpenGL | OpenGL Red Book, Chapters 4 (Color), 5 (Lighting), 9 (Texture Mapping)<br>CMU slides on OpenGL shading CMU slides on texture mapping | |
| | Structured deformable objects: cloth | | |

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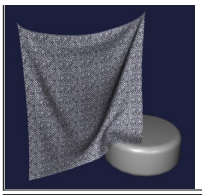
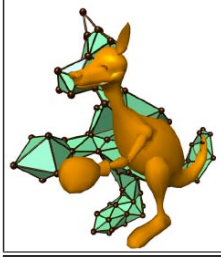
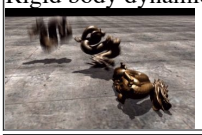
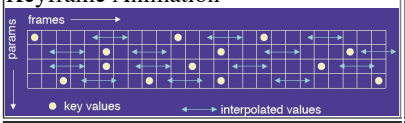
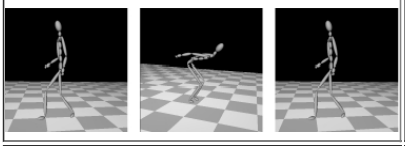
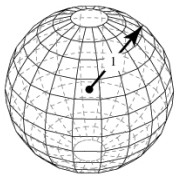
| Mon Feb 4 |  | Slides (thanks to Andy Pierce, USC REU)<br><br>D. Baraff and A. Witkin: Large steps in cloth simulation, SIGGRAPH 1998 | |
| Wed Feb 6 | Structured deformable objects: FEM<br>  | M. Mueller and M. Gros: Interactive virtual materials, Graphics Interface 2004<br><br>J. Barbic: Real-time Reduced Large-Deformation Models and Distributed Contact for Computer Graphics and Haptics , PhD thesis, 2007 (pages 33-42)<br><br>M. Mueller and co-organizers: Real-time physics, course notes, SIGGRAPH 2008 (pages 43-51)<br><br>S. Capell, S. Green, B. Curless, T. Duchamp, Z. Popovic: Interactive Skeleton-Driven Dynamic Deformations, SIGGRAPH 2002 | |
| Mon Feb 11 | Rigid body dynamics<br>  | D. Baraff and A. Witkin: Physically Based Modeling, course notes (the chapter on Rigid Body Dynamics), SIGGRAPH 2001 | |
| Wed Feb 13 | Keyframe Animation<br>  | Lecture slides | **Assignment 1 due** |
| Mon Feb 18 | No class (President's Day) | | |
| Wed Feb 20 | Motion capture<br>  | Jessica Hodgins's slides on motion capture<br><br>J. Lee, J. Chai, P. Reitsma, J. Hodgins, N. Pollard: Interactive Control of Avatars Animated with Human Motion Data, SIGGRAPH 2002<br><br>J. Barbic, A. Safonova, J. Pan, C. Faloutsos, J. Hodgins, N. Pollard: Segmenting Motion Capture Data into Distinct Behaviors, Graphics Interface, 2004 | **Assignment 2 out** |
| Mon Feb 25 | Quaternions<br>  | Course slides<br><br>Ken Shoemake: Animating rotation with quaternion curves, SIGGRAPH 1985<br><br>Alan H. Barr, Bena Currin, Steven Gabriel, John F. Hughes: Smooth interpolation of orientations with angular velocity constraints using quaternions, SIGGRAPH 1992 | |
| Wed Feb 27 | Inverse Kinematics<br>  | Rick Parent's slides on Inverse Kinematics<br><br>Chris Welman: Inverse Kinematics and Geometric Constraints for Articulated Figure Manipulation, M.S. Thesis, Simon Fraser University, 1993 | |
| Mon Mar 4 | Character Rigging<br>  | Ladislav Kavan, Steven Collins, Jiří Žára, Carol O'Sullivan: Geometric Skinning with Approximate Dual Quaternion Blending, ACM Transaction on Graphics, 27(4), 2008 | |
| | Facial Animation | Ming Lin's course slides on facial animation Digital Emily video Video on | |

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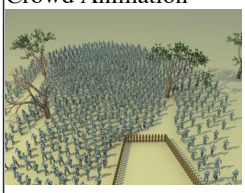
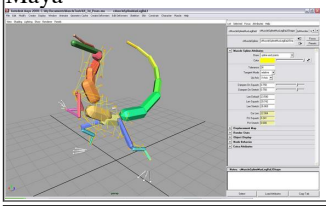
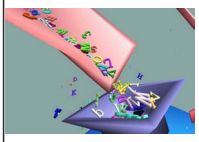
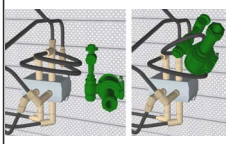
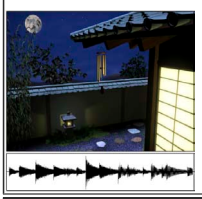
| Wed Mar 6 |  | paired muscles<br><br>Jun-yong Noh, Ulrich Neumann: A Survey of Facial Modeling and Animation Techniques, University of Southern California<br><br>E. Sifakis, I. Neverov and R. Fedkiw: Automatic Determination of Facial Muscle Activations from Sparse Motion Capture Marker Data, SIGGRAPH 2005 | |
| Mon Mar 11 | Crowd Animation<br>  | Craig W. Reynolds: Flocks, herds and schools: A distributed behavioral model, SIGGRAPH 1987.<br>SIGGRAPH 1997 course notes A pseudocode implementation<br><br>Matt Anderson, Eric McDaniel and Stephen Chenney: Constrained Animation of Flocks, Symposium on Computer Animation 2003<br><br>Crowd research at UNC<br><br>Course slides on crowd animation, Ohio State University | |
| Wed Mar 13 | Maya<br>  | Maya tutorials at Lynda.com (free of charge access for USC students).<br><br>Autodesk: The Art of Maya<br><br>The Maya scene used in class. | **Assignment 2 due** |
| Mon Mar 18 | No class (spring break) | | |
| Wed Mar 20 | No class (spring break) | | |
| Mon Mar 25 | Maya | | |
| Wed Mar 27 | Constraints and contact | D. Baraff and A. Witkin: Physically Based Modeling, course notes (the chapters "Constrained Dynamics" and "Collision and Contact"), SIGGRAPH 2001 | **Assignment 3 out** |
| Mon Apr 1 | Collision detection<br>  | Ming Lin's course slides on collision detection \| PDF Collision detection at UNC, Chapel Hill<br><br>Ming Lin's course slides on bounding volume hierarchies and spatial partitioning \| PDF<br><br>S. Gottschalk, M. Lin, D. Manocha: OBB-Tree: A Hierarchical Structure for Rapid Interference Detection, SIGGRAPH 1996<br><br>S. Quinlan: Efficient Distance Computation between Non-Convex Objects, ICRA 1994 | |
| Wed Apr 3 | Haptics<br>  | K. Salisbury and F. Conti: Haptic Rendering: Introductory Concepts, IEEE Computer Graphics, 2004 (a survey)<br><br>M. Lin and M. Otaduy: Recent Advances in Haptic Rendering & Applications, SIGGRAPH 2005 Course Notes<br><br>J. Barbic and D. James: Six-DoF Haptic Rendering of Contact between Geometrically Complex Reduced Deformable Models, IEEE Transactions on Haptics 2008 | |
| Mon Apr 8 | Sound simulation<br>  | J. O'Brien, C. Shen, and C. Gatchalian: Synthesizing Sounds from Rigid-Body Simulations, SCA 2002 | |

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| Wed Apr 10 | Fluids (Navier-Stokes)<br>  | J. Stam: Stable Fluids, SIGGRAPH 1999<br><br>Stable Fluids presentation | |
| Mon Apr 15 | Catch-up day | Catch-up day | |
| Wed Apr 17 | Simulation on programmable graphics hardware (GPUs)<br>  | Slides on shaders and GPUs<br>C. Everitt: OpenGL ARB Vertex Program, E. Hart: OpenGL ARB Fragment Program, Game Developers Conference 2003<br>L. Wei: A Crash Course on Programmable Graphics Hardware GP-GPU Tutorial<br>OpenGL API OpenGL Shading Language Sample Code & Tutorials Cg (Nvidia) | **Assignment 3 due** |
| Mon Apr 22 | Simulation on programmable graphics hardware (CUDA)<br>  | Nvidia's CUDA<br>Trefftz and Wolffe: Tutorial on CUDA \| (modified; used in class)<br>OpenCL<br><br>J. Georgii, R. Westermann: Mass-spring systems on the GPU | |
| Wed Apr 24 | Guest Lecture: TBA | | |
| Mon Apr 29 | Case study: Havok engine for physics in games<br>  | Slides (ppt)<br><br>Havok Physics Open Dynamics Engine (ODE) | |
| Wed May 1 | Review for exam | | |
| Mon May 13 | Final exam | **2p.m.-4 p.m.** | |

## Prerequisites

- A grade of at least B in CS480 or CS580, or explicit permission of instructor. If you took a similar course at another university, contact the instructor.
- Familiarity with calculus, linear algebra, and numerical computation
- C/C++ programming skills

## Readings

There is no required textbook. Selected articles and course notes will be made available online.

A good reference on computer animation:

- Rick Parent: **Computer Animation, Second Edition: Algorithms and Techniques**, Second edition, Publisher: Morgan Kaufmann, ISBN: 9780125320009

A reference book on OpenGL is recommended for help with the homeworks:

- Dave Shreiner: **OpenGL Programming Guide: The Official Guide to Learning OpenGL, Versions 3.0 and 3.1**, Seventh edition, Publisher: Addison-Wesley Professional, ISBN: 9780321552624

## Assignments

There will be three programming homework assignments in C/C++ and OpenGL, related to the material covered in class. Please see the schedule for links to assignments and due dates. All assignments must be done **individually.**

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## Grading

- Assignments: 21% each (63% total)
- Final exam: 37%

All assignments must be completed to pass the course. The assignments will have a small amount of extra credit.

**Late policy:** Programming assignments should be turned in by midnight on the day they are due. A total of **three late days** may be taken during the semester on programming assignments. For example, you can use one late day on the second assignment, and two on the third assignment. All days are counted, including any weekends and holidays, as follows:
Less than 24 hours late = 1 late day, 24-48 hours late = 2 late days, 48-72 hours late = 3 late days, and so on.
The flexibility provided by the late days is intended to get you through the time where all your classes just happen to have assignments due on the same day. Beyond the three late days, there will be a penalty of 10% of the value of the assignment / day. Exceptions will be granted only under most dire circumstances and must be discussed with and approved by the instructor at least one week in advance.

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## Academic integrity

All students are expected to maintain the utmost level of academic integrity. Do not copy any parts of any of the assignments from anyone. Do not look at other students' code, papers, assignments or exams. The university policies on academic conduct will be applied rigorously, and the USC Office of Student Judicial Affairs and Community Standards will be notified.

Please consult the USC Student Guidebook (for example, Section 11.00 in the University Governance chapter) for details on what is and is not appropriate, and for the possible consequences of violating the rules. USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

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## Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations c an be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.-5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.