CPSC 4050/6050: Introduction to 3D Computer Graphics

Spring 2021

Section(s): 6050: 001; 4050: 001
When: MW 2:30-3:45
Where: Live online zoom sessions, recorded and posted to ensemble
Instructor: Jerry Tessendorf
Email: jtessen@clemson.edu
Office: McAdams 302
Office Hours: Wednesdays 9am-12pm, link announced each day in canvas. Also by appointment.

TA:
TA Office Hours:
TA Email:
Webpage:
Videos
Syllabus
Slack

DESCRIPTION

A broad introduction to 3D computer graphics theory and practice. The representation, generation, manipulation, and rendering of 3D objects in a computer graphics environment. Topics may include

- The pillars of 3D computer graphics
  - modeling geometry
  - light and shade geometry
  - viewing 3D world
  - sampling 3D world
- Points, Vectors and Vector Algebra
  - what is a vector?
  - geometric interpretation of a vector
  - additive operations
  - dot product
  - cross product
  - solving geometric problems with vector algebra
- Storage and display of Images
  - pixmaps
  - greyscale and RGB color
  - color systems and color spaces
  - ACES and OpenColorIO
  - color displays and output devices
  - LUTS (http://www.redsharknews.com/post/item/2966-the-beginners-guide-to-luts)
  - image file formats and libraries
  - conversion between formats
  - OpenEXR and OpenImageIO
  - OpenGL routines
- Geometry I
  - lines
  - planes
  - spheres
- Rendering I
  - ray casting
  - ray intersection with geometry
  - a raycasting renderer for planes and spheres
- Shading I
  - lightings
  - ambient, diffuse and specular reflection
  - Phong shading model
- Geometry II
  - polygons
  - polygonal surfaces and data structures
  - implicit and parametric surface representations
  - blobbies
  - quadrics
- Rendering II
  - global vs. local illumination
  - rendering equation
  - recursive raytracing as a solution
  - accelerated raycasting
- Matrices and matrix algebra
  - matrix representation
  - matrix-vector multiplication
  - the 2D and 3D affine transforms
- Coordinate systems and camera models
  - coordinate system transformations
  - representations for rotations
  - camera models
- Rigging and Animating Geometry
  - rigging concepts
  - weighting models
  - keyframe animation
  - procedural animation
  - pose space deformation
  - delta-mush
- Rendering III
  - screen space vs. object space renderers
  - projection systems, orthographic and perspective
  - homogeneous coordinates
  - scan conversion (rasterization)
- Geometry III
OBJECTIVES

This course is designed to train students in the basic principles of 3D Computer Graphics, so that they will be able to

- understand the internal workings of commercial systems for the rendering of digital images from 3D models
- write their own software for 3D modeling and rendering
- use 3D graphics API's
- undertake creative work and research in 3D graphics

Students attend lectures, read, discuss, and complete quizzes. They also complete several programming projects designed to expand their practical knowledge of the field of 3D graphics.

SCHEDULE

Below is the intended schedule for the semester, and is subject to change to adapt to unexpected circumstances. Any changes will be updated in this schedule.

<table>
<thead>
<tr>
<th>Week</th>
<th>Monday</th>
<th>Wednesday</th>
<th>Friday</th>
<th>Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 4-8</td>
<td>No class</td>
<td>Introduction to course</td>
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<tr>
<td>Jan 11-15</td>
<td>3D Vectors and manipulations of vectors</td>
<td>3D Matrices and manipulations</td>
<td>Ch 2,3</td>
<td></td>
</tr>
<tr>
<td>Jan 18-22</td>
<td>Planes, triangles, spheres</td>
<td>Ray intersections with planes and triangles</td>
<td>Assignment 1 due</td>
<td>Ch 5.1,5.2</td>
</tr>
<tr>
<td>Jan 25-29</td>
<td>Ray intersections with spheres</td>
<td>digital images, pixels, color</td>
<td>Ch 6.2,6.3</td>
<td></td>
</tr>
<tr>
<td>Feb 1-5</td>
<td>Pin hole camera. A basic ray tracer.</td>
<td>Reflection, shading</td>
<td>Assignment 2 due</td>
<td>Ch 6.4,7</td>
</tr>
<tr>
<td>Feb 8-12</td>
<td>OpenGL display of images</td>
<td>Polygons, texture coordinates, vertex normals</td>
<td>Project 1 due</td>
<td>Ch 7.5</td>
</tr>
<tr>
<td>Feb 15-19</td>
<td>Surfaces: meshes, blobbies, quadratics</td>
<td>implicit surfaces, surfs surfaces</td>
<td>Assignment 3 due</td>
<td></td>
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<tr>
<td>Feb 22-26</td>
<td>The rendering equation</td>
<td>BRDFs</td>
<td>Assignment 4 due</td>
<td></td>
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<tr>
<td>Mar 1-5</td>
<td>Monte Carlo (recursive, iterative) ray tracing</td>
<td>Acceleration structures</td>
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<tr>
<td>Mar 8-12</td>
<td>Coordinate transforms</td>
<td>Local and global coordinates</td>
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<td></td>
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<tr>
<td>Mar 15-19</td>
<td>SPRING BREAK</td>
<td>SPRING BREAK</td>
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</tr>
<tr>
<td>Mar 22-26</td>
<td>Polynomial curves and surfaces</td>
<td>Beplines rational beplines</td>
<td>Assignment 5 due</td>
<td></td>
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<tr>
<td>Mar 29-Apr 2</td>
<td>Geometry file formats</td>
<td>Subdivision surfaces</td>
<td>Project 2 due</td>
<td></td>
</tr>
<tr>
<td>Apr 5-9</td>
<td>FK, IK, Rigging</td>
<td>Animation</td>
<td>Assignment 6 due</td>
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<tr>
<td>Apr 12-16</td>
<td>Image Based Lighting</td>
<td>Particles, noise</td>
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<tr>
<td>Apr 19-23</td>
<td>Volumes</td>
<td>Production Pipelines, Departments, Responsibilities</td>
<td>Assignment 7 due</td>
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</tbody>
</table>

FINAL EXAM

OTHER TEXTBOOKS


RESOURCES

- Google C++ Style Guide
- Software Packages Documentation:
  - OpenGL Programming Guide
  - OpenGL Reference Manual
  - Mark J. Kilgard, *The OpenGL Utility Toolkit (GLUT)* Programming Interface API
  - OpenImageIO documentation
  - OpenEXR documentation
  - ImageMagick documentation
  - ImageMagick Documentation
  - FFTW: Fastest Fourier Transform in the West
  - RIMI Documentation
  - A 3D Vector class Vector.h

GRADING

Most of the grade will be based on two kinds of evidence: written assignments demonstrating your understanding and use of concepts, and coding projects.
demonstrating your practical understanding of the implementation of an algorithm(s).

There are 7 written assignments and 2 coding/programming projects in this class. Each written assignment is worth 10 points. Each coding project is worth 15 points. There are also 10 points possible for class participation (participation means several different things: questions during lectures, correcting the lecturer during lectures, coming to office hours, and other ways you might think of to raise overall participation). The worst grade of your assignments will be discarded, so that only 6 of the 7 will contributed to your grade. The total maximum points is 100 (60 for assignments + 30 for projects + 10 for participation).

The grade is relative to the percentage of 100 points achieved.

Grades: A > 90%; B > 80%; C > 70%; D > 60%; F < 60%

For each coding project, the allocation of the 15 points will be based on the following considerations:

1. Does it work as expected and efficiently? (9)
2. Is the code clean, organized, demonstrate pride of craftsmanship, and easy to build? (6)

Each assignment has a due date, and there is no opportunity to hand them in late. The two projects also have due dates, and there are no provisions for handing them in late.

For both assignments and projects, if you are having trouble completing them, you are encouraged to come to office hours and share your problems with the instructor and/or TA. If the due date and time is approaching, you are better off handing in material that is incomplete or not working, than handing in nothing at all. Partial credit can be given for incomplete/incorrect work, but no credit can be given when nothing is handed in.

ASSIGNMENTS
The assignments require written products. The process for turning them in is through the handin system described below. The format of the submission is flexible. It can be, e.g. a pptx, docx, or pdf file, as long as it is viewable on a linux computer. If you work entirely hand-written on paper, you could scan or photograph the pages, bundle the images into a zip file (as described below), and submit that.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Due Date</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Assignment 1: ????</td>
<td>January 22 23:59:59</td>
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<tr>
<td>Assignment 2: ????</td>
<td>February 05 23:59:59</td>
<td></td>
</tr>
<tr>
<td>Assignment 3: ????</td>
<td>February 19 23:59:59</td>
<td></td>
</tr>
<tr>
<td>Assignment 4: ????</td>
<td>March 05 23:59:59</td>
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<tr>
<td>Assignment 5: ????</td>
<td>March 26 23:59:59</td>
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<td>Assignment 6: ????</td>
<td>April 08 23:59:59</td>
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<td>Assignment 7: ????</td>
<td>April 23 23:59:59</td>
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</table>

CODING PROJECTS
All of the coding projects involve programming in C++. Work may be done on any computer supporting C++, but the grade will be based on my ability to compile and run your code on a School of Computing linux computer. For reference purposes, students are provided with a "starter kit" with a basic implementation of particle motion and display, which students may use as the basis of their own assignments, if they choose.

<table>
<thead>
<tr>
<th>Project</th>
<th>Due Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1: ????</td>
<td>February 12 23:59:59</td>
<td>4050 Students: 6050 Students:</td>
</tr>
<tr>
<td>Project 2: ????</td>
<td>April 02 23:59:59</td>
<td>4050 Students: 6050 Students:</td>
</tr>
</tbody>
</table>

ASSIGNMENT AND PROJECT HAND IN
Assignments and projects will be handed in using the School of Computing handin mechanism https://handin.cs.clemson.edu/. The assignment needs to be encapsulated in a zip file before it is submitted. The zip file should have the very specific name username.zip where username is YOUR username. For example, if I submit assignment 2, it should be in a zip file named jtessen.zip.

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**IT IS VERY IMPORTANT THAT YOU CAREFULLY FOLLOW THIS REQUIREMENTS. FAILURE TO DO SO WILL COST YOU POINTS. DONT MESS UP ON THE SMALL STUFF.** Documentation exists on the website.

You have several choices in how you submit the assignment:

1. Use a browser to log into the Webhandin website, handin.cs.clemson.edu, and submit the .zip file of the assignment. This can be done from any computer.
2. Use the linux command, handin, to submit the .zip file.

Remember that you can submit to handin as many times as you like until the expiration date of the assignment. Only the last submitted version will be graded. So it is safe to submit an incomplete assignment early, just to make sure that the submission process functions, then later do it again for the version of the assignment you actually want a grade on.

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**IT IS YOUR RESPONSIBILITY TO ENSURE THAT YOUR ASSIGNMENT MAKES ITS WAY TO THE HANDIN SYSTEM, REGARDLESS OF THE PERFORMANCE OF THE TOOLS PROVIDED. YOU CAN DOUBLE CHECK WITH WEBHANDIN TO VERIFY THE SUCCESS OF YOUR UPLOAD.**

Keep in mind that it is safe to hand in an assignment/project more than once before the deadline. The last submission will be the one that is graded. Handing in a partially completed assignment early is a good way to make sure that you understand the technical steps to do it, and if an unexpected crisis happens and you miss the deadline, then at least you have submitted something that gives you partial credit.
Communications

Communications between the students and instructor/TA will be via the following mechanisms:

1. Zoom: this will be the video conference platform for live lectures and online office hours. During the live lectures, students are highly encouraged to ask questions and challenge the lectures, via direct questioning of the instructor in the video conference, or via asking questions or commenting on the chat. The instructor will monitor the chat and seek to answer any questions during the lecture. Invitations will be generated for each individual zoom session and posted on Canvas.

2. Ensemble: Lectures will be recorded and posted to ensemble.clemson.edu at the URL listed at the top of the syllabus.

3. Canvas: Announcements for the class will be posted to canvas, including the Zoom meeting invitations. Canvas will also be the location where assignment grades are posted.

4. Email: This mechanism is available as a means of having one-on-one conversations if needed. In unforeseen circumstances, announcements to the class may be posted via email.

The primary tools for communications from instructor to students will be Zoom (lectures) and Canvas (announcements, grades).

Policies

Conduct Policy

Students are expected to be courteous and respectful in all interactions with fellow class members, TAs, and the instructor (whether this interaction occurs online, during class, or outside of class). Student misconduct will not be tolerated. Student misconduct includes, but not limited to, arguing with an instructor or TA about course policies, being rude or disrespectful towards a fellow class member or an instructor, sleeping in class, disrupting class, using a computer or other device during class without authorization from the instructor, showing up to class late or leaving class early without permission from the instructor, and refusing to follow course policies or instructions stated by an instructor. The instructor and TAs have the right to assign seats or to ask students to move to another seat if they feel it is necessary, and refusing to sit in an assigned seat will also be considered as an act of student misconduct. NO tobacco products or electronic cigarettes are allowed to be used during class or labs, including cigarettes, cigars, chewing tobacco, dip, etc. For the first case of student misconduct, students may have points deducted from their Quiz grades or their final grade might be lowered by one full letter grade (i.e. an A becomes a B, B becomes a C, etc.) at the instructor’s discretion. In extreme cases, or if the misconduct persists, a grade of F will be assigned to the student, and the student will not be allowed to attend class thereafter.

Academic Honesty

"As members of the Clemson University community, we have inherited Thomas Green Clemson’s vision of this institution as a high seminary of learning. Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form."

When, in the opinion of a course instructor, there is evidence that a student has committed an act of academic dishonesty, the instructor must make a formal written charge of academic dishonesty, including a description of the misconduct to Dr. Jeff Appling, Associate Dean of Undergraduate Studies. The reporting instructor may, at his/her discretion, inform each involved student privately of the nature of the alleged charge. In cases of plagiarism (I.B.2.) instructors may use the Plagiarism Resolution Form available from the Office of Undergraduate Studies.

Steps to help prevent academic dishonesty are:

1. Familiarize yourself with the regulations.
2. Refuse to assist students who want to cheat.
3. Protect your work! Do not allow anyone to copy any part of your work, and report anyone who tries to copy from you to the instructor or TA.
4. Do not copy any code from an unauthorized source. An unauthorized source includes, but not limited to, any webpage, online source, document, book, or person not affiliated with our course.
5. If you have any doubt about what constitutes academic dishonesty, ask your instructor before you turn in an assignment.

Furthermore, selling, posting, or giving away course content such as slides, notes, or any information about exams, quizzes, assignments, projects, or lectures is considered an act of academic dishonesty (unauthorized assistance) unless you have written permission from the instructor. All work submitted for grades should be your own work, and you cannot copy, paraphrase, or modify any work from any source not explicitly permitted by the instructor. The instructor has the right to run programs to detect evidence of unauthorized assistance (usually in the form of copying from another person or unauthorized source) in any assignment submitted by a student in this semester, previous semesters, or future semesters. Cheating has severe consequences, please do your own work!

Class Accommodation and Accessibility

Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to a class should let the professor know, and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848, by emailing studentaccess@lists.clemson.edu, or by visiting Suite 239 in the Academic Success Center building. Appointments are strongly encouraged, drop-ins will be seen if possible, but there could be a significant wait due to scheduled appointments. Students who receive Academic Access Letters are strongly encouraged to request, obtain and present these to their professors as early in the semester as possible so that accommodations can be made in a timely manner. It is the student’s responsibility to follow this process each semester.

You can access further information here: http://www.clemson.edu/campus-life/campus-services/sds/.

Inclement Weather Policy

If a class is cancelled due to inclement weather, the instructor will make alternative arrangements for submitting work that was due that day. Usually the work will be due the next class, unless specified otherwise.

Academic Continuity Plan for this course

Clemson has developed an Academic Continuity Plan for academic operations. Should university administration officially determine that the physical classroom facility is not available to conduct classes in, class will be conducted in a virtual (online) format. The University issues official disruption notifications through email /www/text notification/Social Media. When notified, students will use Clemson Canvas to find important information about the class. Teachers will also provide students with information on what to do in this case.

Late Instructor Policy

If the instructor or a lab instructor is late to class or labs, then students should wait at least 15 minutes and check the course announcements before leaving.

Clemson University Title IX (Sexual Harassment)

Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation,
Syllabus Policy

Students are responsible for learning and following all policies stated in this syllabus. This course syllabus is a general plan for the course; deviations announced to the class by the instructor may be necessary. Tentative course schedule will be frequently updated.