CSCE 645 Geometric Modeling

Instructor: Wenping Wang FALL 2023

For students interested in Computer Graphics, Computer Vision, Robotics, Computer Animation, Data Visualization, VR/AR, and 3D Printing.

<u>Curves and Surfaces</u> in Industry Design CAD

- Bezier Curves
- B-Splines, T-Splines
- NURBS

<u>Subdivision Surfaces</u> in Game Character Design

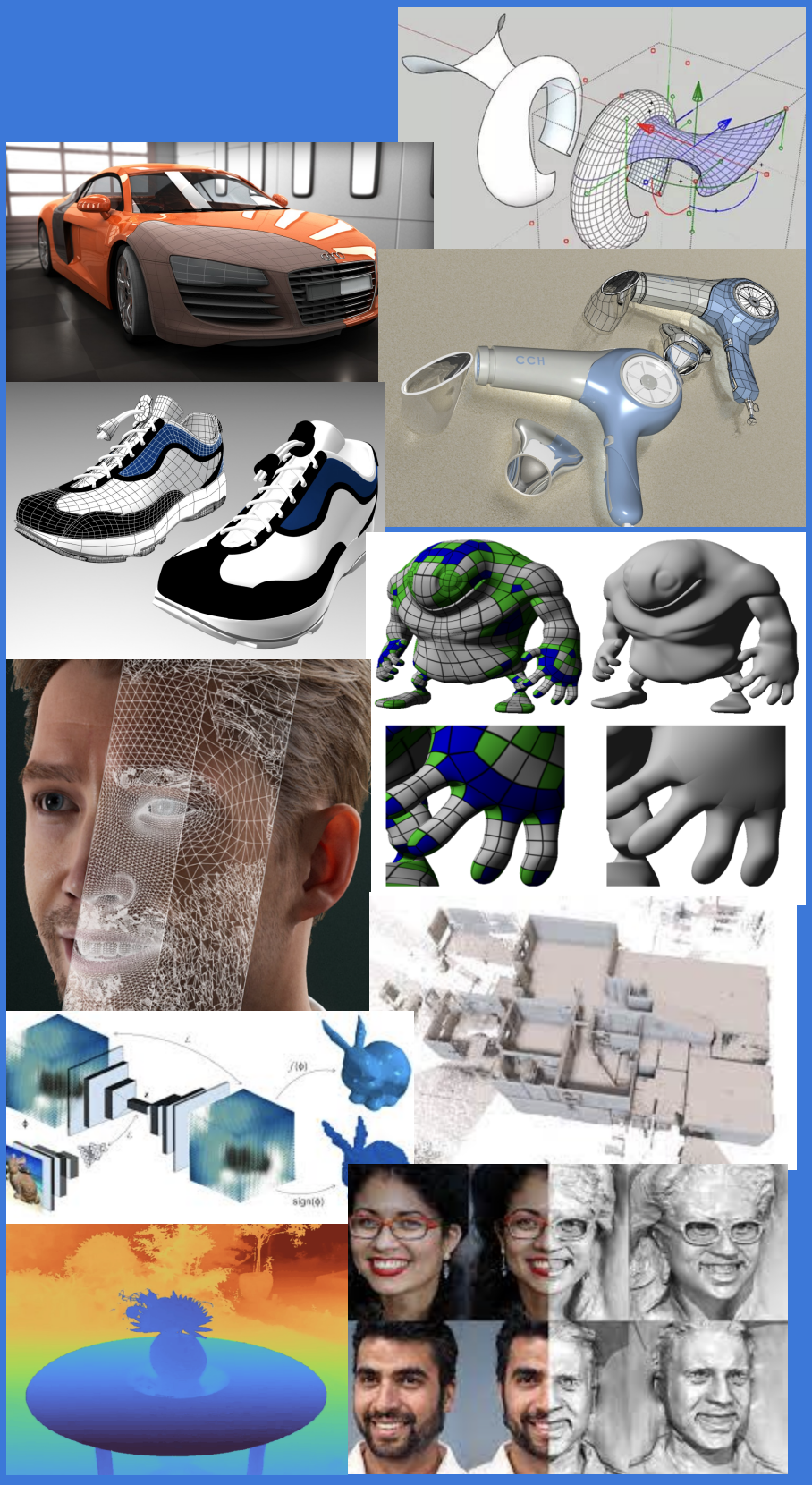
- Catmull-Clark Surfaces
- Loop Surfaces

<u>Meshes and Point Clouds</u>

- Mesh Editing
- 3D Reconstructions

<u>Neural Representations</u>

- Implicit Surfaces
- Neural Rendering



Course Information

Course Number:	CSCE 645 / VIZA 675
Course Title:	Geometric Modeling
Section:	600
Time:	5:30 pm - 6:45 pm on Tuesday and Thursday
Location:	HRBB 126
Credit Hours:	3 hours

This course provides a comprehensive foundation in geometric computing and shape modeling for graduate students who study or conduct research in visual computing, including computer graphics, computer vision, computer animation, VR/ CAD/CAM, scientific data visualization, and medical imaging.

The course will introduce the basic concepts of Euclidean geometry, affine geometry, projective geometry, and differential geometry, from a computational point of view. It covers geometric representations commonly used in visual computing, including Bezier curves and surfaces, B-spline curves and surfaces, subdivision surfaces, mesh surfaces, point cloud surfaces, implicit surfaces, as well as the emerging neural implicit surface representation.

Instructor Details

Instructor:	Wenping Wang
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Office Hours:	4:00 pm to 5:00 pm, Tuesday and Thursday
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Course Description

(This is the catalog description): **Geometric and solid modeling concepts, Freeform curves and surfaces (splines and Bezier) with their relational, intersectional and global mathematic properties; parametric representation of solids, topology of closed curved surfaces, boundary concepts and Boolean/Euler operators; construction and display of curves and surfaces, and solid models.**

This class is intended to give students both a broader understanding of geometric and solid modeling (through class discussions and homework assignments) and in-depth experience with a particular geometric modeling topic (through a course project). This class is intended to provide the background necessary for students who may be conducting research that includes a geometric modeling component. Among the specific topics to be covered:

- Euclidean, affine, and projective geometry
- Differential geometry of curves and surfaces
- Parametric and spline curves and surfaces
- Subdivision curves and surfaces

- Implicit surfaces
- Mesh surfaces and point clouds
- Fitting curves and surfaces to data points
- Voronoi diagram and Delaunay triangulation. Mesh generation
- Solid modeling paradigms and operations
- Robustness and accuracy in geometric computations
- 3D reconstruction from point clouds or 2D images
- Neural representations and rendering

Course Prerequisites

CSCE 441 (Computer Graphics) and 442 (Scientific Computing) are listed as prerequisites in the course catalog. These are *not* enforced requirements. While having these classes will be helpful, you should be able to do fine in the class even if you haven't had them.

You are expected to be able to develop code in a general programming language (e.g. C++ or Python); some homework assignments may include coding components and you are expected to have significant coding in your course project.

It is assumed that you are familiar with linear algebra. Also, you should feel comfortable writing programs involving mathematical manipulation. For example, you should feel OK about writing a routine to find the determinant of a matrix, in the process of coding in a homework assignment. Some graphics (OpenGL) programming may be used, but if so, we will provide necessary skeleton code and review/training so that those without such experience will be able to complete the work.

Course Learning Outcomes

By the end of the class, students should be able to:

- Define the major terms and concepts in geometric and solid modeling
- Determine appropriate methods for solving various geometric modeling problems
- Generate explicit or implicit curve or surface representations to fit given data points.
- Apply known algorithms to evaluating and manipulating different curve, surface, and solid representations.
- Synthesize existing research literature about a topic of current geometric interest
- Create a new approach to address a geometric problem of current interest and evaluate its effectiveness.

Textbook and/or Resource Materials

There is not a required textbook for this course. Course notes and related research papers will be provided for the topics covered and will be available in Canvas.

There is no single textbook that covers all the topics we will address in the course, but there are existing textbooks that cover portions of the material, and often provide much more information about related

topics. The first of these is probably the most generally useful, and is also available as an electronic book from the library (note: you may need to be VPN'd in to TAMU to access it).

- Farin, G. *Curves and Surfaces for CAGD, a Practical Guide, 5th edition*. Morgan Kaufmann, 2001.
    - ebook link | ScienceDirect

Other books that may be useful include:

- Cohen, Riesenfeld, Elber, *Geometric Modeling with Splines, An Introduction*. AK Peters, Natick, MA, 2001.
- Mortenson, M. *Geometric Modeling*. Industrial Press, Inc., 2006.
- Hoschek, J, Lasser, D. *Fundamentals of Computer Aided Geometric Design*. AK Peters, 1993.
- Hoffmann, C. M. *Geometric and Solid Modeling, An Introduction*. Morgan Kaufmann Publishers, San Mateo, CA, 1989.
    - Available online

Grading Policy

There will be no exams in the class. Note that although there is no final exam, the class expects to meet during that time for project presentations, so please keep it open (the specific schedule for that day will be decided later in the semester and will depend on enrollment). Five homework assignments (each equally weighted) will count for half the overall grade, and a course project of the student's choosing will count for the remaining half.

Homeworks:	*50%*
Project:	*50%*

Note that the homework assignments may include both written and programming portions, as well as reading reports on assigned research papers. The course project will require a literature review, coding/implementation, and write-ups of a chosen research topic. The details for these will be provided separately.

The expected grading scale will be A $\geq$ 90% > B $\geq$ 80% > C $\geq$ 70% > D $\geq$ 60% > F. Depending on the final percentage distribution, an absolute or relative curve may be applied, although students should not expect that this will happen. In addition, the instructors reserve the right to change grades near a "borderline" to the next higher **or lower** letter grade. Factors weighing into this decision will be the individual student's perceived effort, attendance, and class participation.

Late Work Policy

Assignments are due at the beginning of the class on the due date assigned. Late assignments will not be accepted without prior discussion. See information below about excused absences.

If students have extenuating circumstances beyond university excused absences, such as a paper deadline that conflicts with a homework deadline, the instructors may grant a homework extension without penalty. Students should notify the instructors as soon as they are aware of such an issue in order to be considered for an extension.

Course Schedule

The following schedule is subject to change as we see how the course progresses.

Week	Topic	Homework Due Dates	Project Deadlines
1 (8/21)	Affine geometry. Affine, convex combinations. Barycentric coordinates; Euclidean geometry, rigid transformations.	First lecture: August 22, 2023, Tuesday.	
2 (8/28)	3D rotations and unit quaternions. Projective geometry. Homogeneous coordinates.		
3 (9/4)	Algebraic curves. Polynomial parametric curves. Bernstein basis functions and Bezier curves.		
4 (9/11)	Rational representations. Differential Geometry of curves. Continuity of curves.	HW 1 (9/12)	
5 (9/18)	Splines, including B-splines and NURBS. T-splines. Fitting spline curves to data points.		
6 (9/25)	Tensor-product surfaces, Bezier triangles. Coons patches. Fitting surfaces to data points.		
7 (10/2)	Differential geometry of surfaces: First and second fundamental forms, curvatures and geodesics. Minimal surfaces.	HW 2 (10/3)	Proposal (10/5)
8 (10/9)	Subdivision surfaces: Catmull-Clark surfaces, Loop surfaces. (Fall break 10/10, Tuesday, no class).		
9 (10/16)	Volumetric models. B-reps, topological representations and operations, robustness.	HW 3 (10/17)	
10 (10/23)	Convex hull, Voronoi diagrams, Delaunay triangulation. Mesh generation. Medial axis transform.		Update 1 (10/26)
11 (10/30)	Implicit surfaces. Neural implicit representation. Constructive Solid Geometry (CSG).		
12 (11/6)	Mesh surfaces. Mesh surface editing, mesh surface simplifications. Mesh quality improvement.	HW 4 (11/7)	
13 (11/13)	3D reconstruction from point clouds or 2D images.		Update 2 (11/16)
14 (11/20)	Neural rendering and representations. (Thanksgiving on 11/23, Thursday, no class)	HW 5 (11/21)	
15 (11/27)	Topics TBD (optional topics or project presentations) (Last week of the semester)		
Exam week (12/6 – 12/12)	Last day of fall semester 12/4, Monday. Final Exam Time: Project Presentations		Project Presentation, Final Report (12/12)

University Policies

Attendance Policy

The university views class attendance and participation as an individual student responsibility. Students are expected to attend class and to complete all assignments.

Please refer to Student Rule 7 in its entirety for information about excused absences, including definitions, and related documentation and timelines.

Makeup Work Policy

Students will be excused from attending class on the day of a graded activity or when attendance contributes to a student's grade, for the reasons stated in Student Rule 7, or other reason deemed appropriate by the instructor.

Please refer to Student Rule 7 in its entirety for information about makeup work, including definitions, and related documentation and timelines.

Absences related to Title IX of the Education Amendments of 1972 may necessitate a period of more than 30 days for make-up work, and the timeframe for make-up work should be agreed upon by the student and instructor" (Student Rule 7, Section 7.4.1).

"The instructor is under no obligation to provide an opportunity for the student to make up work missed because of an unexcused absence" (Student Rule 7, Section 7.4.2).

Students who request an excused absence are expected to uphold the Aggie Honor Code and Student Conduct Code. (See Student Rule 24.)

Academic Integrity Statement and Policy

"An Aggie does not lie, cheat or steal, or tolerate those who do."

"Texas A&M University students are responsible for authenticating all work submitted to an instructor. If asked, students must be able to produce proof that the item submitted is indeed the work of that student. Students must keep appropriate records at all times. The inability to authenticate one's work, should the instructor request it, may be sufficient grounds to initiate an academic misconduct case" (Section 20.1.2.3, Student Rule 20).

You can learn more about the Aggie Honor System Office Rules and Procedures, academic integrity, and your rights and responsibilities at aggiehonor.tamu.edu.

Americans with Disabilities Act (ADA) Policy

Texas A&M University is committed to providing equitable access to learning opportunities for all students. If you experience barriers to your education due to a disability or think you may have a disability, please contact the Disability Resources office on your campus (resources listed below)

Disabilities may include, but are not limited to attentional, learning, mental health, sensory, physical, or chronic health conditions. All students are encouraged to discuss their disability related needs with Disability Resources and their instructors as soon as possible.

Disability Resources is located in the Student Services Building or at (979) 845-1637 or visit disability.tamu.edu.

Title IX and Statement on Limits to Confidentiality

Texas A&M University is committed to fostering a learning environment that is safe and productive for all. University policies and federal and state laws prohibit gender-based discrimination and sexual harassment, including sexual assault, sexual exploitation, domestic violence, dating violence, and stalking.

With the exception of some medical and mental health providers, all university employees (including full and part-time faculty, staff, paid graduate assistants, student workers, etc.) are Mandatory Reporters and must report to the Title IX Office if the employee experiences, observes, or becomes aware of an incident that meets the following conditions (see University Rule 08.01.01.M1):

- The incident is reasonably believed to be discrimination or harassment.
- The incident is alleged to have been committed by or against a person who, at the time of the incident, was (1) a student enrolled at the University or (2) an employee of the University.

Mandatory Reporters must file a report regardless of how the information comes to their attention – including but not limited to face-to-face conversations, a written class assignment or paper, class discussion, email, text, or social media post. Although Mandatory Reporters must file a report, in most instances, a person who is subjected to the alleged conduct will be able to control how the report is handled, including whether or not to pursue a formal investigation. The University's goal is to make sure you are aware of the range of options available to you and to ensure access to the resources you need.

Students wishing to discuss concerns in a confidential setting are encouraged to make an appointment with Counseling and Psychological Services (CAPS).

Students can learn more about filing a report, accessing supportive resources, and navigating the Title IX investigation and resolution process on the University's Title IX webpage.

Statement on Mental Health and Wellness

Texas A&M University recognizes that mental health and wellness are critical factors that influence a student's academic success and overall wellbeing. Students are encouraged to engage in healthy self-care by utilizing available resources and services on your campus

Students who need someone to talk to can contact Counseling & Psychological Services (CAPS) or call the TAMU Helpline (979-845-2700) from 4:00 p.m. to 8:00 a.m. weekdays and 24 hours on weekends. 24-

hour emergency help is also available through the National Suicide Prevention Hotline (800-273-8255) or at suicidepreventionlifeline.org.